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# MONTANA LARGE APERTURE SEISMIC ARRAY

Robert E. Matkins

Philco-Ford Corporation

Prepared for:

Advanced Research Projects Agency

15 March 1973

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MONTANA LARGE APERTURE SEISMIC ARRAY

FIFTH QUARTERLY TECHNICAL REPORT, PROJECT VT 2708

CONTRACT F33657-72-C-0390

1 DECEMBER 1972 - 28 FEBRUARY 1973

15 March 1973

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13. ABSTRACT

The technical activity associated with the operation, maintenance, and improvement of the Montana Large Aperture Seismic Array (LASA) during the period 1 December 72 - 28 February 73 is related in this report. The short-period (SP) and long-period (LP) seismograph sensitivity performance statistics are indicated. The measured free period and mass position characteristics for the LP seismometer array are presented. Development of pseudo-random binary sequence (PRBS) calibration technique for the remote measurement of the amplitude, phase, and sensitivity characteristics of the LP seismograph over a broad band of frequencies is reported. Improvement to the PRBS calibrations recently developed for the SP seismograph is described. Statistics relating to the operation and maintenance of the array and data center equipment and land facilities support are provided.

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# MONTANA LARGE APERTURE SEISMIC ARRAY

## FIFTH QUARTERLY TECHNICAL REPORT

15 March 1973

### IDENTIFICATION

AFTAC Project No.: VELA T/2708

Project Title: Montana Large Aperture Seismic Array

ARPA Order No.: 1620

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Philco-Ford Corporation

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## ACRONYMS

| | |
|---|---|
| AFSC | Air Force Systems Command |
| AMSR | Alternate Management Summary Report |
| ARPA | Advanced Research Projects Agency |
| ASPR | Armed Services Procurement Regulations |
| CTH | Central Terminal Housing |
| DCASD | Defense Contract Administration Services District |
| IRSPS | Integrated Seismic Research Signal Processing System |
| LASA | Large Aperture Seismic Array |
| LASAPS | LASA Processing Subsystem |
| LDC | LASA Data Center |
| LMC | LASA Maintenance Center |
| LP | Long-Period |
| MDC | Maintenance Display Console |
| MOPS | Multiple On-line Processing System |
| NEIC | National Earthquake Information Center |
| PMEL | Precision Measurement and Equipment Laboratory |
| PRBS | Pseudo-Random Binary Sequence |
| SAAC | Seismic Array Analysis Center |
| SDL | Seismic Data Laboratory |
| SEM | Subarray Electronics Module |
| SP | Short-Period |
| VLR | Very Low Rate |
| VSC | VELA Seismological Center |
| WHV | Well Head Vault |

SECTION I

# INTRODUCTION

This report presents the accomplishments and administration of Contract Number F33657-72-C-0390. This contract between the Philco-Ford Corporation and AFSC Aeronautical Systems Division is for continued operation, research, and development of the Montana Large Aperture Seismic Array (LASA).

The LASA is part of the Vela Uniform Program which is sponsored by the Advanced Research Projects Agency (ARPA) of the Department of Defense. LASA is an experimental system consisting of many seismometers installed near Miles City, Montana, (Figure 1.1) used for the development of appropriate methods for the detection and identification of seismic events. Initially, the detection, location, and identification of seismic data were performed at the LASA Data Center (LDC) located at Billings, Montana. However, subsequent to implementation of the Integrated Seismic Research Signal Processing System (IRSPS), the array data is now transmitted to the Seismic Array Analysis Center (SAAC) in Alexandria, Va., for processing and analysis.

## 1.1 History

The LASA, installed in Eastern Montana during 1964 and 1965, is used for experiments in advanced seismological detection and discrimination. The initial installation, composed of 21 subarrays geometrically placed at a diameter of 200 kilometers with 525 short-period and 63 long-period seismometers, has evolved into the present array with the original 21 subarrays reduced to 346 short-period seismometers and 51 long-period seismometers.

Philco-Ford's participation in the Montana LASA began in 1964 by providing MIT Lincoln Laboratory with field engineering assistance. In June 1966, Philco-Ford assumed operational and maintenance responsibilities for MIT Lincoln Laboratory. On 1 May 1968, the project direction was transferred to the Electronics Systems Division, AFSC, with prime contracts to Philco-Ford through 30 November 1970.

On 1 December 1970, technical direction of the Montana LASA was assigned to the Vela Seismological Center (VSC). Under Projects V/T 1708 and V/T 2708 Philco-Ford continues the work of previous Montana LASA projects. This work basically involves the continued operation and maintenance of the array and data center systems, logistics and administrative support, data provision, and hardware evaluation and installation.

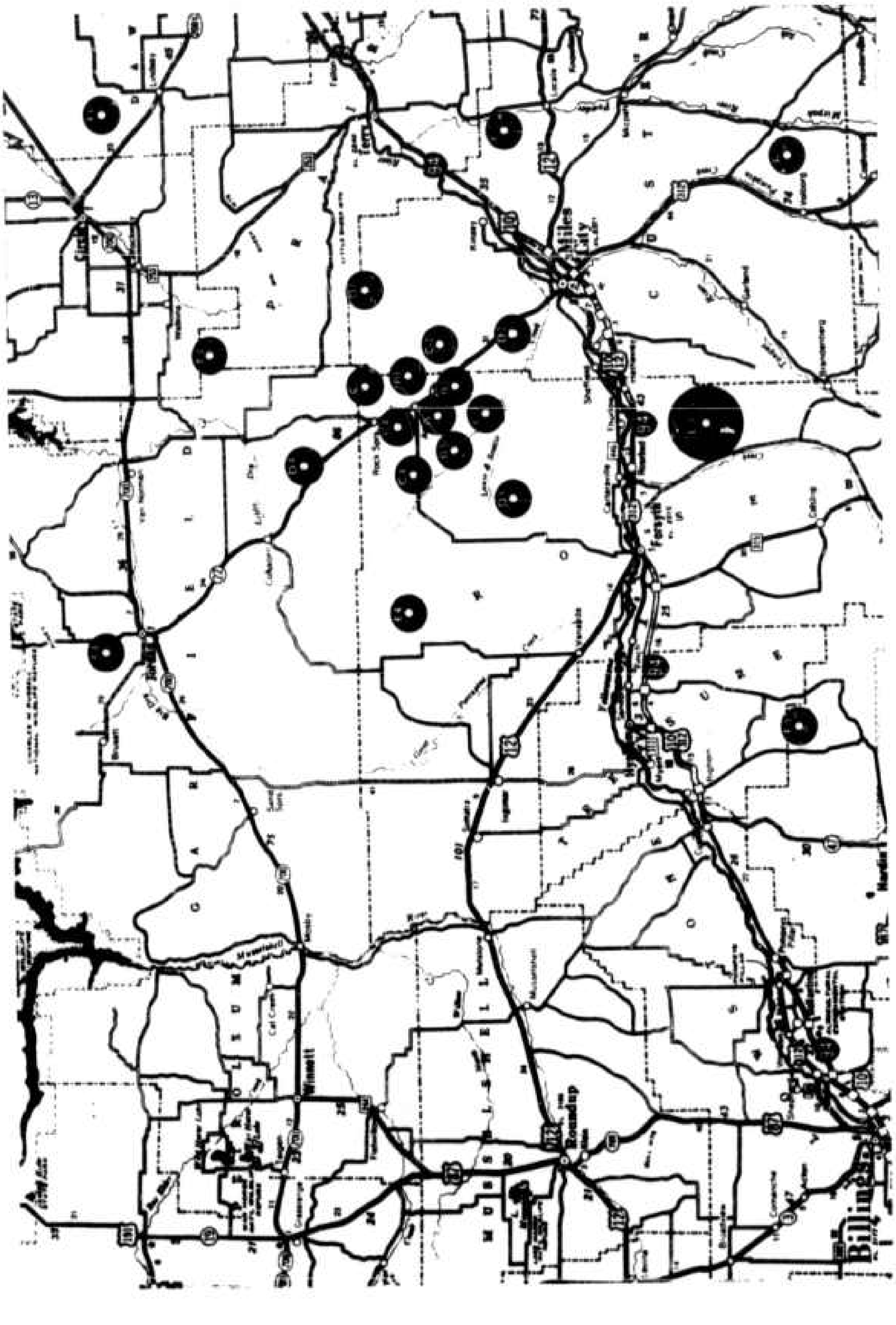



Figure 1.1 Montana LASA

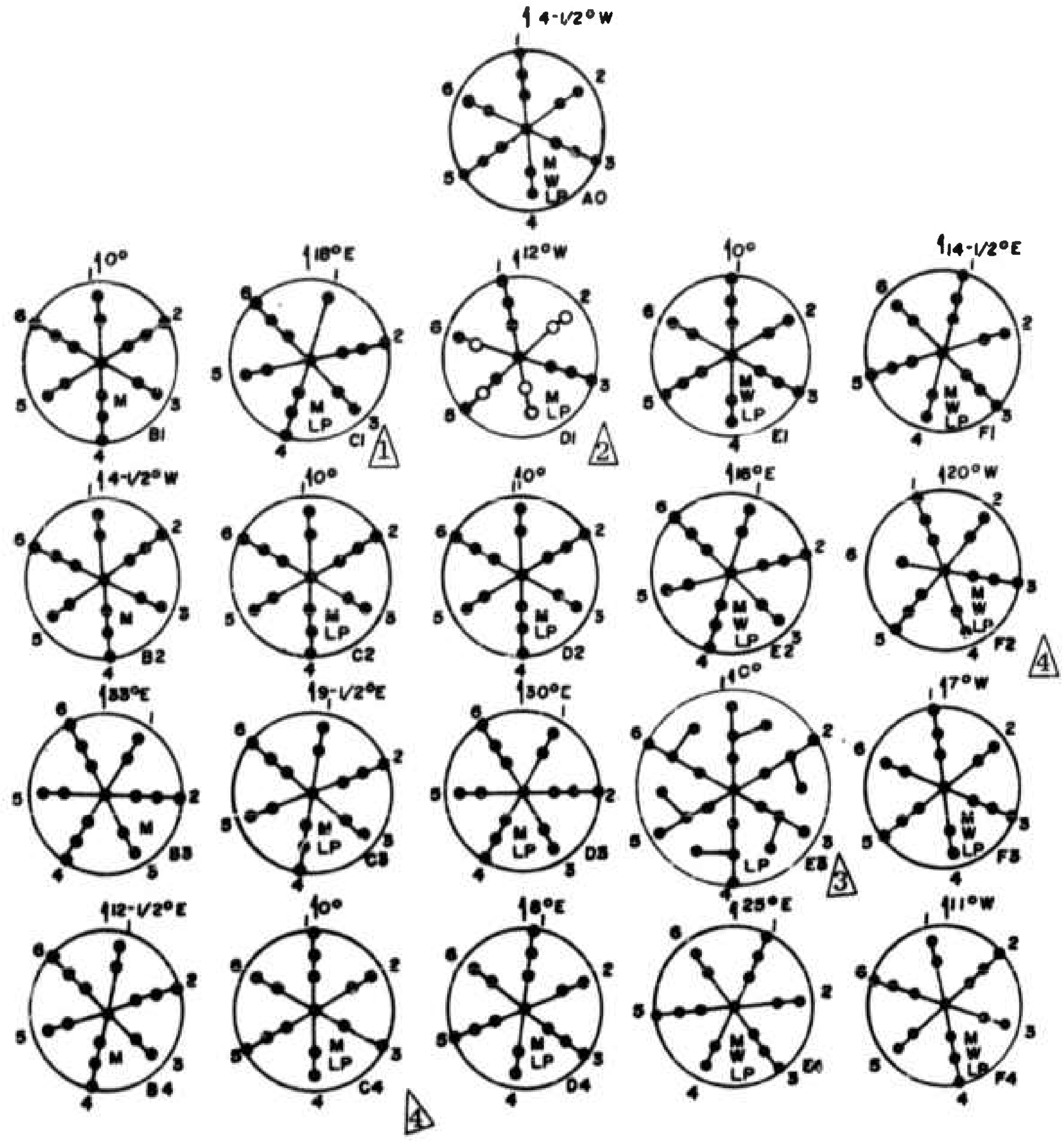
## 1.2 Description

The LASA with an overall diameter of 200 kilometers (124 miles) is composed of 21 subarrays arranged as shown in Figure 1.1. With the exception of subarray E3 which is 19 km in diameter, all subarrays are 7 km in diameter. Subarray E3 is configured with 25 short-period seismometers while others now have 16. All subarrays originally were designed with 25 seismometers each, however, programmed sensor removal has now lowered this number to 16 except at E3. The short-period seismometers are located along six radial cables which terminate in a central under-ground vault containing the Subarray Electronics Module (SEM). The subarrays also contain three-component long-period sensors, and weather sensors. Figure 1.2 shows the present configuration of each subarray.

The LDC controls the array operation by sending a command signal to each SEM at a rate of twenty times each second to cause sampling of the subarray signals. This command signal is suitably delayed at the LDC prior to transmission so that data from all SEMs will arrive at the LDC within predetermined time intervals.

The SEM responds to LDC timing system control signals with signal sampling, conversion, and transmission of all data to the LDC. Flexibility exists within the array in that the SEM can accomodate as many as 30 signal inputs; currently, signals from short and long-period seismometers, weather sensing equipment, and other measured parameters are telemetered. Signals from the 21 SEM's are transmitted to microwave junction points by open wire lines at a 19.2 kilobaud rate; from these points they are sent to the LDC by microwave radio facilities. At the LDC the data are processed and reformatted for transmission over a 50 kilobaud channel to SAAC. The LDC also contains the array timing and maintenance monitoring equipment. By means of telemetry commands, signal sources at the subarray are controlled to provide equipment calibrations and verify equipment performance.

The different LASA seismographs operating parameters and tolerances are identified in Tables I and II. Figure 1.3 shows the five different seismograph responses available.




▷ Notes

1. SP Sensors removed from leg 1 because of access difficulties
2. 0 denotes near surface SP sensors
3. Expanded subarray, 18 km diameter
4. SP sensor inoperative and lost in cased hole

All degrees shown are orientations with respect to true north. The letters LP, M, and W denote long period seismic, microbarograph, and weather sensors installed at the center of the subarray. Microbarograph data was not available for transmission to SAAC after March 24, 1972.

Figure 1.2 LASA Subarray Configurations

TABLE I

LASA SEISMOGRAPH OPERATING PARAMETERS AND TOLERANCES

| CHANNEL IDENT. | OPERATING PARAMETERS AND TOLERANCES | | | | |
|---|---|---|---|---|---|
| | $T_s$ | $\lambda_s$ | $(MP_s)$ | $S_{chan}$ | Full Scale Within |
| SPZ | 1.0±0.1 | 0.7±0.1 | | 20±3mV/nm@1.0s | 609-823nm@1.0s |
| SPIZ | " | " | | " | " |
| SPTZ | 1.15 | 0.7 | | " | " |
| SPTN | 1.06 | " | | " | " |
| SPTE | 1.03 | " | | " | " |
| SPAZ | 1.0±0.1 | 0.7±0.1 | | 636±95mV/μm@1.0s | 19.2-25.9μm@1.0s |
| LPZ | 20.0±5% | 0.77 | 0±1.5mm | 350±50mV/μm@25s | 35.0-46.7μm@25s |
| LPH | " | " | " | " | " |
| LPAZ | " | " | " | 11±1.7mV/μm@25s | 1102-1505μm@25s |
| LPAH | " | " | " | " | " |
| LPWZ | " | " | " | 55±8.3mV/μm@25s | 221-300μm@25s |
| LPWH | " | " | " | " | " |

LEGEND: $T_s$ = Seismometer Free Period (Sec); $\lambda_s$ = Seismometer Damping

$(MP_s)$ = Seismometer Mass Position from Center

$S_{chan}$ = Channel Sensitivity

TABLE II

LASA SEISMOGRAPH CHANNEL IDENTIFICATION

| CHANNEL | MANUFACTURER/MODEL | SEISMIC AMPLIFIER MFGR/MODEL | FILTER MFGR/MODEL/TYPE |
|---|---|---|---|
| SPZ | GeoSpace/HS-10-1A | Texas Inst./RA-5 | 4 pole ½dB ripple Chebyshev low pass, $f_c$=5.0 hertz, @10 hertz, -30dB. |
| SPAZ | GeoSpace/HS-10-1A | Texas Inst./RA-5 | |
| SPIZ | GeoSpace/HS-10-1B | Ithaco/6072-65 | " |
| SPTZ | Teledyne/TD-201D | Texas Inst./RA-5 | " |
| SPTN | Teledyne/TD-201D | Texas Inst./RA-5 | " |
| SPTE | Teledyne/TD-201D | Texas Inst./RA-5 | " |
| LPZ | Geotech/7505A | Texas Inst./Type II | Texas Inst./Type II/Response A. 24 dB/oct high-cut, centered at 65 sec. |
| LPH | Geotech/8700C | Texas Inst./Type II | |
| LPAZ | Geotech/7505A | Texas Inst./Type II | " |
| LPAH | Geotech/8700C | Texas Inst./Type II | " |
| LPWZ | Geotech/7507A | Texas Inst./Type II | Texas Inst./Type II/Response C. 12 dB/oct high-cut, centered at approx. 100 sec. |
| LPWH | Geotech/8700C | Texas Inst./Type II | |

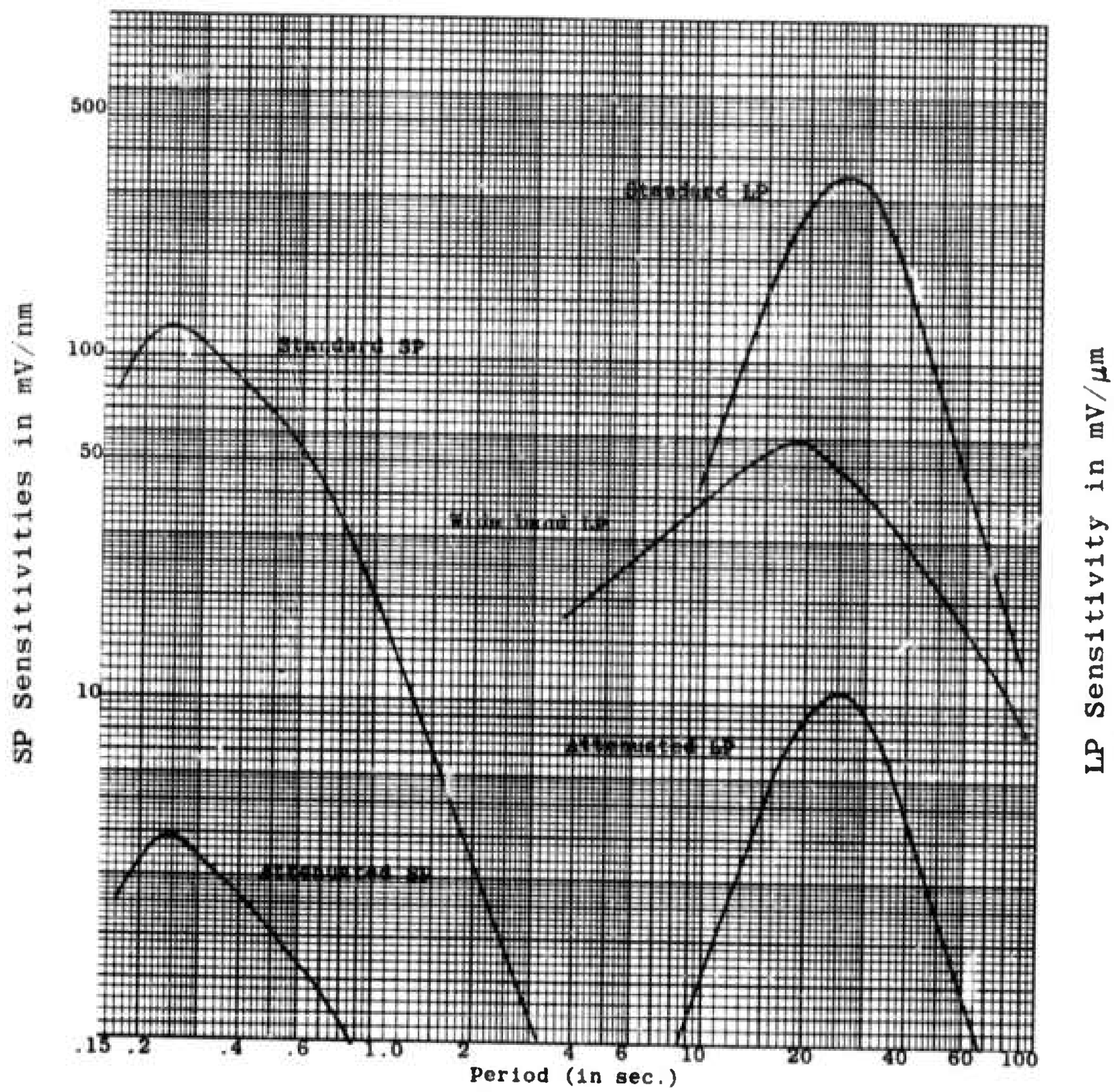



Figure 1.3 LASA Seismographs Response Curves

## SECTION II

## SUMMARY

Montana LASA operations support provided to SAAC was 95.4% for on-line data transmission and 4.6% for back-up data recording bringing the contract totals for these percentages to 95.0 and 5.0 respectively.

Array monitoring and remote calibrations continue to provide information necessary in the measurement of equipment performance. Seismograph sensitivities averaged 20.1 mV/nm at 1s and 362 mV/$\mu$m at 25s for the short (SP) and long-period (LP) channels respectively. Improvement in the stability of the SP seismographs was noted; however, the LP system measurements reflected a decrease in the number of sensors operating within the sensitivity tolerance. Calibration signal coupling into the data signal lines from moisture within the LP seismometer tank is the suspected source of this observation, that is, erroneous measurement data instead of poor seismograph performance. Replacing the silica jel inside the tank of the seismometers effected has corrected the trouble.

Remote measurement of the LP seismometers free period and mass position shows an average free period of 20.02 sec/cycle with an average weekly variation of 0.01 sec/cycle and mass positions centered within an average of -0.19 mm with an average variation of 0.12 mm/week.

Development of a pseudo-random binary sequence (PRBS) calibration technique for the remote measurement of the amplitude, phase, and sensitivity characteristics of the LP seismographs over a frequency range of interest has been completed. The initial set of data for the 51 instruments of the array has been prepared for study and analysis. The calculation of sensitivities has been added to the SP system PRBS calibration technique. Calibrations of the SP and LP arrays are now being performed near the middle of each month with the actual times reported for users interested in this new technique.

Maintenance activity consisted primarily of subarray preventive maintenance and channel adjustments, shop repair of spares, and PDP-7 computer repairs.

## SECTION III

## OPERATION

### 3.1 General

Array operation is performed to provide data continuously from the array sensing and data acquisition systems to the LDC, to provide data on-line from the LDC to the SAAC. and to provide data recording in the event data transmission to SAAC is interrupted.

### 3.2 Data Center

The LASA Data Center (LDC) contains the equipment necessary to process the seismic array data either for transmission to SAAC or for recording locally. The activities in support of the LASAPS and other data center systems include: (1) IBM 360/44 computer operation on-line to SAAC, (2) PDP-7 computer operation to record array data in back-up of the 360 computer and to perform array monitoring, automatic calibrations, and off-line processing of array performance information, (3) maintenance display console operation for test and diagnosis of array equipment performance, (4) tape and film library operation for storage, handling, and shipment of array data recordings, (5) Develocorder operation for continuous recording of selected sensor channels for the Seismic Data Laboratory (SDL) and array quality control testing and analysis, and (6) telemetry link operation for continuous on-line data transmission of selected seismograph channels to MIT for data analysis.

### 3.2.1 SAAC/LDC Systems

Operation of the real-time data link between the SAAC and LDC so that a maximum amount of useful seismic data from the Montana array reaches SAAC for analysis is one of the main goals of our data center's operation. Monitoring of the SAAC/LDC operation during this quarterly period produced the operational statistics in Table III. Three operational modes which cause the outages shown are: (1) the SAAC computers are not available for LASAPS data acquisition, (2) the LDC Model 44 computer is not available for processing LASAPS data, and (3) the wideband communications channel between the LDC and SAAC is not in operation. These outage times are covered with digital recordings of the LASA data by the PDP-7 computer; however, no real time data is available at SAAC. Periods in which LASAPS data was not used in the IRSPS operation at SAAC totaled 100.2 hours so that for 95.36% of this reporting period the SAAC/LDC systems operated together. The wideband data link between the two centers was inoperative 17.0 hours or 0.78% of the period.

TABLE III

SAAC/LDC SYSTEM OPERATING TIMES

Dec. 72 - Feb. 73

| | DEC. | JAN. | FEB. | TOTALS |
|---|---|---|---|---|
| SAAC & LDC 360 On-Line | 672.9 | 730.8 | 656.1 | 2059.8 |
| SAAC Off-Line, LDC 360 Running | | | | |
| PDP-7 Recording | 26.3 | 11.4 | 7.0 | 44.7 |
| 360 Training | 0.0 | 0.0 | 0.0 | 0.0 |
| SAAC Up, LDC 360 Down, PDP-7 Recording | | | | |
| Scheduled | 2.8 | 1.7 | 4.3 | 8.8 |
| Unscheduled | 26.8 | 0.0 | 2.0 | 28.8 |
| SAAC Up, Other Equipment Down, PDP-7 Recording | | | | |
| Scheduled | 0.0 | 0.0 | 0.0 | 0.0 |
| Unscheduled | 15.2 | .1 | 2.6 | 17.9 |
| Totals (in hours) | 744.0 | 744.0 | 672.0 | 2160.0 |

### 3.2.2 IBM/360 Model 44 Computer

The IBM/360 computer, the LASAPS data processor, was fully operational at the LDC for 98.22% of this quarter. The complete computer utilization statistics are given in Table IV. On-line processing time equalled 95.36% of the period. Maintenance activities used 37.6 hours or 1.74% of the available time.

### 3.2.3 DEC PDP-7 Computer

The DEC PDP-7 computer was fully operational for data center processing 99.3% of this quarter of which on-line processing accounted for 82.35% and off-line 17.65%. The complete summary of computer utilization statistics are shown in Table V. The back-up operating mode of high-rate recording (Ref. 1) was required on 91 occasions covering an accumulated time period of 106.6 hours. During this operation 804 magnetic tapes were recorded by the computer on 49 of the 90 days of this reporting period. Low rate recordings totaling 934.6 hours were also made. Both low rate and high rate recordings are retained at the LDC for at least 30 days of recycle time prior to reuse.

### 3.2.4 Analog System

Two Geotech Model 4000 Develocorders are operated at the LDC. One is used to support data analysis work at SDL and the other to support array maintenance by providing a means to display various sensor outputs during different intervals of time. The SDL Develocorder is operated 24 hours a day and each film record is scanned in the film viewer to determine the quality of the film record and provide a log of occurrences which affect the quality and usability of the film record.

### 3.2.5 Tape/Film Library

The data center's library is used to store the PDP-7 computer magnetic tape recordings, the 360 computer disc recordings, and the Develocorder film recordings (prior to distribution) for reuse or reference. As of February 28, PDP-7 high-rate back-up recordings dating back to 14 December 1972 were in the library awaiting request or recycling. With the receipt of 400 tapes from Patrick AFB, the library presently contains 1180 tapes.

The library use statistics for this quarter are:

804 PDP-7 high rate tapes retained for recycling

700 PDP-7 low rate tapes retained for recycling

## 3.3 Array

Array operations functions performed include (1) monitoring of all array systems to detect equipment and data degradation, (2) testing of all array systems to measure equipment

TABLE IV

SYSTEM/360 MODEL 44 COMPUTER UTILIZATION

Dec. 72 - Feb. 73

| OPERATION | ACCUMULATED TIME, HOURS | | | |
|---|---|---|---|---|
| | DEC. | JAN. | FEB. | TOTALS |
| On-line processing including: | | | | |
| Fully operational with SAAC | 672.9 | 730.8 | 656.1 | 2059.8 |
| Running at LASA only | 26.3 | 11.4 | 7.0 | 44.7 |
| Down-time operating including: | | | | |
| Scheduled maintenance | 2.8 | 1.7 | 4.3 | 8.8 |
| Corrective maintenance | 26.6 | 0.0 | 2.0 | 28.6 |
| Training | 0.0 | 0.0 | 0.0 | 0.0 |
| Shut down - 360 equipment | 0.2 | 0.0 | 0.0 | 0.2 |
| Shut down - Other equipment | 14.5 | 0.0 | 2.5 | 17.0 |
| Program halt or loop | 0.7 | 0.1 | 0.1 | 0.9 |
| Idle time | 0.0 | 0.0 | 0.0 | 0.0 |
| Totals | 744.0 | 744.0 | 672.0 | 2160.0 |

TABLE V

PDP-7 COMPUTER UTILIZATION

Dec. 72 - Feb. 73

| OPERATION | ACCUMULATED TIME, HOURS | | | |
|---|---|---|---|---|
| | DEC. | JAN. | FEB. | TOTALS |
| On-line program operation including: | | | | |
| Monitor & Weather Processing only | 256.0 | 243.0 | 231.6 | 730.6 |
| VLR Recording only | 0.0 | 0.0 | 0.0 | 0.0 |
| High Rate Recording only | 69.4 | 14.3 | 17.3 | 101.0 |
| Low Rate Recording only | 312.0 | 354.3 | 262.7 | 929.0 |
| VLR & High Rate Recording | 0.0 | 0.0 | 0.0 | 0.0 |
| VLR & Low Rate Recording | 0.0 | 0.0 | 0.0 | 0.0 |
| VLR & High & Low Rate Recording | 0.0 | 0.0 | 0.0 | 0.0 |
| High & Low Rate Recording | 4.9 | 0.7 | 0.0 | 5.6 |
| Off-line program operation including: | | | | |
| Tape Duplication & Verification | 0.0 | 0.0 | 0.0 | 0.0 |
| Data Analysis | 0.0 | 4.2 | 65.3 | 69.5 |
| Utility Operation | 55.7 | 41.7 | 58.7 | 156.1 |
| Program Development | 36.9 | 84.5 | 29.3 | 150.7 |
| Diagnostic Programs & Testing | 2.3 | 0.0 | 0.0 | 2.3 |
| Training | 0.0 | 0.0 | 0.0 | 0.0 |
| Down-time operating including: | | | | |
| Scheduled Maintenance | 0.0 | 0.0 | 0.0 | 0.0 |
| Corrective Maintenance | 4.8 | 0.0 | 6.9 | 11.7 |
| Shut down PDP-7 Inoperative | 0.0 | 1.0 | 0.0 | 1.0 |
| Shut down - Other Equipment | 0.0 | 0.0 | 0.0 | 0.0 |
| Program Halts | 2.0 | 0.3 | 0.2 | 2.5 |
| Idle | 0.0 | 0.0 | 0.0 | 0.0 |
| Totals | 744.0 | 744.0 | 672.0 | 2160.0 |

performance characteristics, (3) interfacing with telephone company personnel to determine communications equipment performance, and (4) processing of array maintenance and operation data to obtain statistics and information for efficient array management. These tasks are performed utilizing the PDP-7 computer, the maintenance display console, and the Develocorders. The overall system quality control effo ' s are applied through these activities.

3.3.1 Monitoring

Array monitoring refers to the sensing of performance of the operational equipment through the measurement of equipment characteristics on an essentially continuous basis. At the LDC continuous monitoring of the array systems is accomplished using the built-in data monitors, viz. (1) the MDC alarm monitor panel, (2) the PDP-7 monitor program and (3) the 360 computer's on-line system. The MDC alarm monitor panel provides instantly both a visual and audible indication at the occurrence of either a data link failure between the LDC and a subarray or an alarm signal of subarray power and vault failures transmitted on telemetry word 31. The PDP-7 monitor program outputs each telemetry word 31 data change from any subarray and also prints out the duration of subarray data interruptions. The 360 computer's on-line system program periodically generates a variety of monitoring messages.

Operation and maintenance of the array equipment requires that the data be interrupted at various periods, during which time normal or reliable data may not be available to the LASA data user. The reasons established for data interruptions are: maintenance, either being performed or initiated; subarray equipment failure in which no maintenance has been initiated; telephone company(s) performing tests on the communication link not functioning; power outage at the subarray; or special data center testing. In the event any of these situations occur, a notation is made in the data interruption log relating to the data affected and the time period. For the case of short-period and long-period interruptions, SAAC is alerted via the System 360 typewriter. The total duration of data interruption reported for each subarray is broken down by month in Table VI.

3.3.2 Calibrations

Calibrations are performed from the data center to sense the performance of the operating array equipment through the periodic measurement and/or adjustment of one or more equipment characteristics.

(a) Seismograph Sinusoidal

Sinusoidal calibrations are performed daily for the short-period seismographs and weekly for the long-period systems. A set of telemetry remote controls (Ref. 2) connects the data center with each subarray and provides the means for determining the condition of the array equipment. The PDP-7 computer controls

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES

| | | TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES) | | | |
|---|---|---|---|---|---|
| ARRAY | DATA | DEC. | JAN. | FEB. | TOTALS |
| A0 | SP | 0:0 | :24 | :08 | :32 |
| | LP | 0:0 | :16 | 2:05 | 2:21 |
| | Meteor | 0:0 | :16 | 0:0 | :16 |
| | Telco | :03 | :29 | 6:56 | 7:28 |
| B1 | SP | 0:0 | :19 | :08 | :27 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| B2 | SP | 2:25 | 1:53 | :44 | 5:02 |
| | Telco | 0:0 | :30 | :12 | :42 |
| B3 | SP | :21 | 1:09 | :22 | 1:52 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| B4 | SP | 1:15 | 1:35 | :25 | 3:15 |
| | Telco | 0:0 | 0:0 | 2:38 | 2:38 |
| C1 | SP | 0:0 | 2:49 | :08 | 2:57 |
| | LP | 0:0 | 2:41 | 2:05 | 4:46 |
| | Telco | 0:0 | 0:0 | 1:30 | 1:30 |
| C2 | SP | 0:0 | :08 | :25 | :33 |
| | LP | 0:0 | 0:0 | 2:22 | 2:22 |
| | Telco | 1:00 | 0:0 | 1:26 | 2:26 |
| C3 | SP | 0:0 | :28 | :08 | :36 |
| | LP | 0:0 | 2:43 | 4:15 | 6:58 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (CONTINUED)

| | | TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES) | | | |
|---|---|---|---|---|---|
| SUB ARRAY | DATA | DEC. | JAN. | FEB. | TOTALS |
| C4 | SP | 0:0 | :52 | :08 | 1:00 |
| | LP | 0:0 | :44 | 2:05 | 2:49 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| D1 | SP | 0:0 | :24 | :08 | :32 |
| | LP | 0:0 | :16 | 2:05 | 2:21 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| D2 | SP | 3:17 | 5:36 | 1:04 | 9:57 |
| | LP | 3:17 | 6:36 | 3:01 | 12:54 |
| | Telco | :02 | 0:0 | 0:0 | :02 |
| D3 | SP | :04 | 2:00 | :17 | 2:21 |
| | LP | :04 | 1:52 | 2:14 | 4:10 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| D4 | SP | 0:0 | :48 | 3:06 | 3:54 |
| | LP | 0:0 | :40 | 5:03 | 5:43 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| E1 | SP | 0:0 | 19:38 | :08 | 19:46 |
| | LP | 0:0 | 19:30 | 2:05 | 21:35 |
| | Meteor | 0:0 | 19:30 | 0:0 | 19:30 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| E2 | SP | 0:0 | :30 | 1:42 | 2:12 |
| | LP | 0:0 | :22 | 4:25 | 4:47 |
| | Meteor | 0:0 | :22 | 1:34 | 1:56 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (CONCLUDED)

| | | TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES) | | | |
|---|---|---|---|---|---|
| SUB ARRAY | DATA | DEC. | JAN. | FEB. | TOTALS |
| E3 | SP | 5:01 | 1:34 | :51 | 7:26 |
| | LP | 5:01 | 1:26 | 2:48 | 9:15 |
| | Telco | 0:0 | :17 | 0:0 | :17 |
| E4 | SP | 0:0 | :08 | :51 | :59 |
| | LP | 0:0 | 0:0 | 2:48 | 2:48 |
| | Meteor | 0:0 | 0:0 | :43 | :43 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| F1 | SP | :34 | 1:05 | :17 | 1:56 |
| | LP | :34 | :57 | 2:14 | 3:45 |
| | Meteor | :34 | :57 | :09 | 1:40 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| F2 | SP | :18 | :35 | :08 | 1:01 |
| | LP | :18 | :27 | 2:05 | 2:50 |
| | Meteor | :18 | :27 | 0:0 | :45 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |
| F3 | SP | 0:0 | 3:56 | 1:49 | 5:45 |
| | LP | 0:0 | 3:48 | 3:46 | 7:34 |
| | Meteor | 0:0 | 3:48 | 1:11 | 4:59 |
| | Telco | 0:0 | :17 | :28 | :45 |
| F4 | SP | 0:0 | :26 | :08 | :34 |
| | LP | 0:0 | :18 | 2:05 | 2:23 |
| | Meteor | 0:0 | :18 | 0:0 | :18 |
| | Telco | 0:0 | 0:0 | 0:0 | 0:0 |

the application of the various telemetry command and calibration signals to the subarray(s), measures the signal responses, calculates the seismograph signal parameters, and outputs the data on punched paper tape for off-line printout. Program TESP is used for the short-period seismographs; program TELP for the long-period seismograph (Ref. 3). Normal channel responses to these sinusoidal calibrations are shown in Table VII, where A (volts) is the analog value, A (digital) is the digital value in decimal, and Y is the corresponding equivalent earth motion.

Further, for the interest of the array data user, precise times in which the array seismographs are interrupted for sinusoidal calibrations are reported here. These times are readily available from the PDP-7 computers MOPS on-line monitor program output and are indicated in Tables VIII and IX for the SP and LP sensors respectively. For the short-period calibrations only one calibration time is shown in Table VIII for each week; the daily times are available upon request from the LDC. The equivalent earth motion of the calibration input signals to the seismometers are also shown in the two tables. Equivalent earth motion is determined from SEM channel 30 measurements during the calibration times. SEM channel 30 monitors the output of the sinusoidal oscillators which generate the signals applied to the seismometer.

(b) Seismograph Broadband

Broadband seismograph calibrations using pseudorandom binary sequences (PRBS) as described in reference 4 are now being performed. The time periods and subarrays involved for these tests are indicated in Table X for the benefit of data users interested in this new technique.

(c) LP Seismometer Remote Adjustments

The remote measurement and adjustment of the long-period seismometer positioning is also performed weekly by the PDP-7 computer using the appropriate telemetry commands. Program MASPOS maintains each seismometer mass to within ± 1.4 mm from its center position. Similarly, the seismometer natural frequencies are maintained to within 20 ± 1 seconds/cycle by program FREECK.

The usefulness of performing this calibration remotely is shown by the number of adjustments made. As shown by the number in parenthesis in the LP channel column of Table XI, a total of 189 adjustments were required; an average of 14.5 per week. The majority (78%) of these adjustments were to recenter the seismic mass.

(d) Defective Channels

When the measured responses exceed the tolerances established for a particular channel, an equipment failure is reported to maintenance and to the users of the array data. The

TABLE VII

LASA SEISMOGRAPH CALIBRATION RESPONSE TOLERANCES

| CHANNEL IDENT. | TC | Peak-to-Peak Sinusoidal Amplitudes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $A_{nom}$ Volts | $A_{max}$ Volts | $A_{min}$ Volts | $A_{nom}$ Digital | $A_{max}$ Digital | $A_{min}$ Digital | $Y_{nom}$ | $Y_{max}$ | $Y_{min}$ |
| SPZ | 06[1] | 7.91 | 9.09 | 6.72 | 9257 | 10638 | 7864 | 395nm | 455nm | 336nm |
| SPAZ | 06[1] | .25 | .289 | .214 | 293 | 407 | 236 | 395nm | 455nm | 336nm |
| SPIZ | 06[1] | 7.91 | 9.09 | 6.72 | 9257 | 10638 | 7864 | 395nm | 455nm | 336nm |
| SPTZ | 06[1] | 7.91 | 9.09 | 6.72 | 9257 | 10638 | 7864 | 395nm | 455nm | 336nm |
| SPTN | 06[1] | 7.91 | 9.09 | 6.72 | 9257 | 10638 | 7864 | 395nm | 455nm | 336nm |
| SPTE | 06[1] | 7.91 | 9.09 | 6.72 | 9257 | 10638 | 7864 | 395nm | 455nm | 336nm |
| LPZ | 20[2] | 6.98 | 7.98 | 5.99 | 8168 | 9339 | 7010 | 20.0μm | 22.8μm | 17.1μm |
| LPH | 20[2] | 6.98 | 7.98 | 5.99 | 8168 | 9339 | 7010 | 20.0μm | 22.8μm | 17.1μm |
| LPAZ | 20[3] | 2.77 | 3.19 | 2.34 | 3242 | 3733 | 2738 | 252μm | 290μm | 213μm |
| LPAH | 20[3] | 2.77 | 3.19 | 2.34 | 3242 | 3733 | 2738 | 252μm | 290μm | 213μm |
| LPWZ | 20[2] | 1.10 | 1.26 | 0.93 | 1287 | 1475 | 1088 | 20.0μm | 22.9μm | 16.9μm |
| LPWH | 20[2] | 1.10 | 1.26 | 0.93 | 1287 | 1475 | 1088 | 20.0μm | 22.9μm | 16.9μm |

Note 1. Amplitude measurements corrected for response to 400nm, 1s calibration signal.
2. Amplitude measurements corrected for response to 20μm, 25s calibration signal.
3. Amplitude measurements corrected for response to 222μm, 25s calibration signal.

TABLE VIII

SP ARRAY SINUSOIDAL CALIBRATIONS

| SUBARRAY | Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes | | | | | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 339 4 Dec. 72 | | Day 346 11 Dec. 72 | | Day 353 18 Dec. 72 | | Day 360 25 Dec. 72 | | Day 001 1 Jan. 73 | | |
| | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | |
| A0 | 1522:46 | 406 | 1339:30 | 408 | 1755:42 | 407 | 1342:19 | 407 | 1305:09 | 408 | A0 |
| B1 | 1523:16 | 402 | 1340:00 | 402 | 1756:12 | 402 | 1342:49 | 402 | 1305:39 | 402 | B1 |
| B2 | 1523:46 | 398 | 1340:30 | 398 | 1756:42 | 396 | 1343:19 | 396 | 1306:09 | 396 | B2 |
| B3 | 1524:16 | 415 | 1341:00 | 417 | 1757:12 | 418 | 1343:49 | 416 | 1306:39 | 417 | B3 |
| B4 | 1524:46 | 397 | 1341:30 | 375 | 1757:42 | 390 | 1344:19 | 388 | 1307:09 | 387 | B4 |
| C1 | 1525:16 | 420 | 1342:00 | 420 | 1758:12 | 420 | 1344:49 | 421 | 1307:39 | 421 | C1 |
| C2 | 1525:46 | 402 | 1342:30 | 402 | 1758:42 | 403 | 1345:19 | 403 | 1308:09 | 403 | C2 |
| C3 | 1526:16 | 420 | 1343:00 | 421 | 1759:12 | 421 | 1345:49 | 421 | 1308:39 | 420 | C3 |
| C4 | 1526:46 | 423 | 1343:30 | 425 | 1759:42 | 424 | 1346:19 | 424 | 1309:09 | 423 | C4 |
| D1 | 1527:16 | 405 | 1344:00 | 407 | 1800:12 | 406 | 1346:49 | 403 | 1309:39 | 403 | D1 |
| D2 | 1527:46 | 387 | 1344:30 | 387 | 1800:42 | 388 | 1347:19 | 387 | 1310:09 | 387 | D2 |
| D3 | 1528:16 | 401 | 1345:00 | 402 | 1801:12 | 403 | 1347:49 | 401 | 1310:39 | 400 | D3 |
| D4 | 1528:46 | 412 | 1345:30 | 416 | 1801:42 | 414 | 1348:19 | 413 | 1311:09 | 416 | D4 |
| E1 | 1529:16 | 415 | 1346:00 | 415 | 1802:12 | 415 | 1348:49 | 415 | 1311:39 | 414 | E1 |
| E2 | 1529:46 | 393 | 1346:30 | 388 | 1802:42 | 390 | 1349:19 | 391 | 1312:09 | 391 | E2 |
| E3 | 1530:16 | 406 | 1347:00 | 405 | 1803:12 | 421 | 1349:49 | 427 | 1312:39 | 383 | E3 |
| E4 | 1530:46 | 415 | 1347:30 | 414 | 1803:42 | 414 | 1350:19 | 414 | 1313:09 | 416 | E4 |
| F1 | 1531:16 | 402 | 1348:00 | 403 | 1804:12 | 401 | 1350:49 | 401 | 1313:39 | 403 | F1 |
| F2 | 1531:46 | 410 | 1348:30 | 410 | 1804:42 | 416 | 1351:19 | 410 | 1314:09 | 410 | F2 |
| F3 | 1532:16 | 412 | 1349:00 | 414 | 1805:12 | 413 | 1351:49 | 412 | 1314:39 | 413 | F3 |
| F4 | 1532:46 | 362 | 1349:30 | 361 | 1805:42 | 361 | 1352:19 | 361 | 1315:09 | 361 | F4 |

TABLE VIII

SP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

| SUBARRAY | Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes | | | | | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 008 8 Jan. 73 | | Day 015 15 Jan. 73 | | Day 022 22 Jan. 73 | | Day 029 29 Jan. 73 | | Day 036 5 Feb. 73 | | |
| | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | |
| A0 | 1451:17 | 411 | 1453:56 | 410 | 1438:50 | 410 | 1450:55 | 408 | 1452:16 | 408 | A0 |
| B1 | 1451:47 | 401 | 1454:26 | 401 | 1439:20 | 401 | 1451:25 | 401 | 1452:46 | 401 | B1 |
| B2 | 1452:17 | 396 | 1454:56 | 396 | 1439:50 | 396 | 1451:55 | 396 | 1453:16 | 396 | B2 |
| B3 | 1452:47 | 423 | 1455:26 | 422 | 1440:20 | 421 | 1452:25 | 418 | 1453:46 | 420 | B3 |
| B4 | 1453:17 | 390 | 1455:56 | 393 | 1440:50 | 393 | 1452:55 | 400 | 1454:16 | 380 | B4 |
| C1 | 1453:47 | 422 | 1456:26 | 421 | 1441:20 | 422 | 1453:25 | 422 | 1454:46 | 422 | C1 |
| C2 | 1454:17 | 402 | 1456:56 | 403 | 1441:50 | 403 | 1453:55 | 403 | 1455:16 | 403 | C2 |
| C3 | 1454:47 | 421 | 1457:26 | 420 | 1442:20 | 420 | 1454:25 | 420 | 1455:46 | 420 | C3 |
| C4 | 1455:17 | 423 | 1457:56 | 423 | 1442:50 | 424 | 1454:55 | 423 | 1456:16 | 423 | C4 |
| D1 | 1455:47 | 405 | 1458:26 | 403 | 1443:20 | 405 | 1455:25 | 407 | 1456:46 | 407 | D1 |
| D2 | 1456:17 | 386 | 1458:56 | 386 | 1443:50 | 386 | 1455:55 | 386 | 1457:16 | 386 | D2 |
| D3 | 1456:47 | 403 | 1459:26 | 403 | 1444:20 | 403 | 1456:25 | 403 | 1457:46 | 403 | D3 |
| D4 | 1457:17 | 420 | 1459:56 | 418 | 1444:50 | 417 | 1456:55 | 417 | 1458:16 | 417 | D4 |
| E1 | 1457:47 | 413 | 1500:26 | 414 | 1445:20 | 414 | 1457:25 | 414 | 1458:46 | 414 | E1 |
| E2 | 1458:17 | 386 | 1500:56 | 387 | 1445:50 | 390 | 1457:55 | 388 | 1459:16 | 391 | E2 |
| E3 | 1458:47 | 386 | 1501:26 | 385 | 1446:20 | 386 | 1458:25 | 387 | 1459:46 | 387 | E3 |
| E4 | 1459:17 | 413 | 1501:56 | 416 | 1446:50 | 415 | 1458:55 | 417 | 1500:16 | 415 | E4 |
| F1 | 1459:47 | 405 | 1502:26 | 404 | 1447:20 | 402 | 1459:25 | 404 | 1500:46 | 402 | F1 |
| F2 | 1500:17 | 410 | 1502:56 | 410 | 1447:50 | 410 | 1459:55 | 410 | 1501:16 | 410 | F2 |
| F3 | 1500:47 | 415 | 1503:26 | 414 | 1448:20 | 413 | 1500:25 | 413 | 1501:46 | 414 | F3 |
| F4 | 1501:17 | 361 | 1503:56 | 361 | 1448:50 | 361 | 1500:55 | 361 | 1502:16 | 361 | F4 |

TABLE VIII

SP ARRAY SINUSOIDAL CALIBRATIONS (CONCLUDED)

| SUBARRAY | Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|
| | Day 043 12 Feb. 73 | | Day 051 20 Feb. 73 | | Day 057 26 Feb. 73 | | |
| | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | Start Time (GMT) | P-P Ampl. nm | |
| A0 | 1801:30 | 408 | 1329:48 | 408 | 1533:19 | 408 | A0 |
| B1 | 1802:00 | 401 | 1330:18 | 401 | 1533:49 | 401 | B1 |
| B2 | 1802:30 | 396 | 1330:48 | 396 | 1534:19 | 396 | B2 |
| B3 | 1803:00 | 418 | 1331:18 | 417 | 1534:49 | 420 | B3 |
| B4 | 1803:30 | 391 | 1331:48 | 392 | 1535:19 | 392 | B4 |
| C1 | 1804:00 | 422 | 1332:18 | 422 | 1535:49 | 421 | C1 |
| C2 | 1804:30 | 403 | 1332:48 | 402 | 1536:19 | 403 | C2 |
| C3 | 1805:00 | 420 | 1333:18 | 420 | 1536:49 | 420 | C3 |
| C4 | 1805:30 | 423 | 1333:48 | 424 | 1537:19 | 423 | C4 |
| D1 | 1806:00 | 407 | 1334:18 | 405 | 1537:49 | 406 | D1 |
| D2 | 1806:30 | 386 | 1334:48 | 386 | 1538:19 | 394 | D2 |
| D3 | 1807:00 | 374 | 1335:18 | 373 | 1538:49 | 374 | D3 |
| D4 | 1807:30 | 418 | 1335:48 | 417 | 1539:19 | 416 | D4 |
| E1 | 1808:00 | 414 | 1336:18 | 414 | 1539:49 | 415 | E1 |
| E2 | 1808:30 | 388 | 1336:48 | 390 | 1540:19 | 391 | E2 |
| E3 | 1809:00 | 390 | 1337:18 | 390 | 1540:49 | 388 | E3 |
| E4 | 1809:30 | 418 | 1337:48 | 418 | 1541:19 | 417 | E4 |
| F1 | 1810:00 | 402 | 1338:18 | 403 | 1541:49 | 404 | F1 |
| F2 | 1810:30 | 411 | 1338:48 | 410 | 1542:19 | 411 | F2 |
| F3 | 1811:00 | 414 | 1339:18 | 414 | 1542:49 | 414 | F3 |
| F4 | 1811:30 | 361 | 1339:48 | 361 | 1543:19 | 361 | F4 |

TABLE IX

LP ARRAY SINUSOIDAL CALIBRATIONS

| SUBARRAY | Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude | | | | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|---|---|---|
| | Day 339: 4 Dec. 72 | | | Day 346: 11 Dec. 72 | | | Day 353: 18 Dec. 72 | | | |
| | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | |
| A0 | 1713:08 | 1716:09 | 20.4 | 1605:15 | 1608:54 | 20.0 | 1949:16 | 1952:57 | 20.0 | A0 |
| C1 | " | " | 19.4 | " | " | 18.9 | " | " | 19.0 | C1 |
| C2 | 1721:09 | 1724:09 | 110 | 1615:28 | 1619:02 | 108 | 1959:31 | 2003:18 | 108 | C2 |
| C3 | " | " | 20.7 | " | " | 20.3 | " | " | 20.4 | C3 |
| C4 | 1729:09 | 1732:09 | 21.0 | 1625:41 | 1629:04 | 20.7 | 2009:57 | 2013:21 | 20.7 | C4 |
| D1 | " | " | 20.3 | " | " | 20.4 | " | " | 19.9 | D1 |
| D2 | 1737:09 | 1740:09 | 20.6 | 1635:30 | 1639:01 | 20.3 | 2019:47 | 2023:28 | 20.3 | D2 |
| D3 | " | " | 18.8 | " | " | 19.0 | " | " | 19.0 | D3 |
| D4 | 1745:09 | 1748:09 | 21.1 | 1645:38 | 1649:26 | 20.8 | 2030:04 | 2033:55 | 20.8 | D4 |
| E1 | " | " | 19.4 | " | " | 19.8 | " | " | 19.7 | E1 |
| E2 | 1753:09 | 1756:09 | 20.9 | 1656:08 | 1659:54 | 20.7 | 2040:38 | 2044:17 | 20.8 | E2 |
| E3 | " | " | 20.9 | " | " | 20.2 | " | " | 20.2 | E3 |
| E4 | 1801:09 | 1804:09 | 21.1 | 1706:19 | 1709:57 | 20.5 | 2050:42 | 2054:16 | 20.5 | E4 |
| F1 | " | " | 20.4 | " | " | 20.2 | " | " | 20.2 | F1 |
| F2 | 1809:09 | 1812:10 | 21.0 | 1716:25 | 1720:11 | 20.7 | 2100:44 | 2104:15 | 20.6 | F2 |
| F3 | " | " | 20.4 | " | " | 19.9 | " | " | 20.0 | F3 |
| F4 | 1817:10 | 1820:10 | 19.7 | 1726:49 | 1730:30 | 19.9 | 2110:53 | 2114:34 | 19.9 | F4 |

TABLE IX

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

| SUBARRAY | Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude | | | | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|---|---|---|
| | Day 361: 26 Dec. 72 | | | Day 002: 2 Jan. 73 | | | Day 008: 8 Jan. 73 | | | |
| | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | Start Time (GMT | Stop Time (GMT) | Input Ampl. μm P-P | |
| A0 | 1803:01 | 1806:45 | 20.0 | 1642:58 | 1646:41 | 20.0 | 1730:15 | 1733:41 | 20.0 | A0 |
| C1 | " | " | 19.0 | " | " | 19.0 | " | " | 18.6 | C1 |
| C2 | 1813:19 | 1816:55 | 108 | 1653:16 | 1656:49 | 108 | 1740:16 | 1743:47 | 108 | C2 |
| C3 | " | " | 20.4 | " | " | 20.3 | " | " | 20.3 | C3 |
| C4 | 1823:35 | 1827:12 | 20.7 | 1703:29 | 1707:07 | 20.7 | 1750:27 | 1753:54 | 20.7 | C4 |
| D1 | " | " | 20.4 | " | " | 20.4 | " | " | 20.4 | D1 |
| D2 | 1833:39 | 1837:06 | 20.3 | 1713:34 | 1717:07 | 20.3 | 1800:21 | 1804:01 | 20.3 | D2 |
| D3 | " | " | 19.0 | " | " | 19.0 | " | " | 19.0 | D3 |
| D4 | 1843:43 | 1847:20 | 20.8 | 1723:44 | 1727:31 | 20.8 | 1810:39 | 1814:16 | 20.8 | D4 |
| E1 | " | " | 19.7 | " | " | 19.7 | " | " | 19.7 | E1 |
| E2 | 1854:02 | 1857:30 | 20.7 | 1734:14 | 1738:00 | 20.7 | 1820:59 | 1824:44 | 20.7 | E2 |
| E3 | " | " | 20.1 | " | " | 19.6 | " | " | 19.6 | E3 |
| E4 | 1903:55 | 1907:26 | 20.5 | 1744:25 | 1748:06 | 20.5 | 1831:10 | 1834:51 | 20.5 | E4 |
| F1 | " | " | 20.2 | " | " | 20.2 | " | " | 20.2 | F1 |
| F2 | 1913:55 | 1917:43 | 20.6 | 1754:35 | 1758:10 | 20.6 | 1841:20 | 1844:54 | 20.6 | F2 |
| F3 | " | " | 20.0 | " | " | 20.0 | " | " | 20.0 | F3 |
| F4 | 1924:22 | 1928:07 | 19.9 | 1804:49 | 1808:14 | 19.9 | 1851:33 | 1855:07 | 19.9 | F4 |

TABLE IX

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

| SUBARRAY | Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude | | | | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|---|---|---|
| | Day 015: 15 Jan. 73 | | | Day 022: 22 Jan. 73 | | | Day 029: 29 Jan. 73 | | | |
| | Start Time (GMT) | Stop Time (GMT) | Input Ampl. µm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. µm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. µm P-P | |
| A0 | 1612:20 | 1615:51 | 20.0 | 1659:56 | 1703:44 | 20.0 | 1611:58 | 1615:38 | 20.0 | A0 |
| C1 | " | " | 19.1 | " | " | 19.1 | " | " | 19.1 | C1 |
| C2 | 1622:26 | 1626:16 | 108 | 1710:20 | 1713:51 | 108 | 1622:13 | 1626:00 | 108 | C2 |
| C3 | " | " | 20.4 | " | " | 20.4 | " | " | 20.3 | C3 |
| C4 | 1632:55 | 1636:24 | 20.7 | 1720:31 | 1724:18 | 20.7 | 1632:40 | 1636:23 | 20.7 | C4 |
| D1 | " | " | 20.4 | " | " | 20.4 | " | " | 20.4 | D1 |
| D2 | 1642:51 | 1646:42 | 20.3 | 1730:45 | 1734:37 | 20.3 | 1642:51 | 1646:27 | 20.3 | D2 |
| D3 | " | " | 19.0 | " | " | 19.0 | " | " | 18.9 | D3 |
| D4 | 1653:19 | 1657:12 | 20.8 | 1741:14 | 1744:49 | 20.8 | 1653:04 | 1656:34 | 20.8 | D4 |
| E1 | " | " | 19.7 | " | " | 19.7 | " | " | 19.7 | E1 |
| E2 | 1703:55 | 1707:26 | 20.8 | 1751:32 | 1755:09 | 20.8 | 1703:18 | 1707:00 | 20.7 | E2 |
| E3 | " | " | 19.6 | " | " | 19.6 | " | " | 19.6 | E3 |
| E4 | 1713:51 | 1717:18 | 20.5 | 1801:34 | 1804:59 | 20.5 | 1713:26 | 1716:58 | 20.5 | E4 |
| F1 | " | " | 20.2 | " | " | 20.2 | " | " | 20.2 | F1 |
| F2 | 1723:47 | 1727:28 | 20.6 | 1811:29 | 1815:09 | 20.6 | 1723:27 | 1727:12 | 20.6 | F2 |
| F3 | " | " | 19.9 | " | " | 19.9 | " | " | 19.9 | F3 |
| F4 | 1734:07 | 1737:38 | 19.9 | 1821:49 | 1825:31 | 19.9 | 1733:51 | 1737:31 | 19.9 | F4 |

TABLE IX

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

| SUBARRAY | Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|
| | Day 036: 5 Feb. 73 | | | Day 043: 12 Feb. 73 | | | |
| | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | |
| A0 | 1913:56 | 1917:27 | 20.0 | 1623:12 | 1627:01 | 20.0 | A0 |
| C1 | " | " | 19.1 | " | " | 19.1 | C1 |
| C2 | 1924:03 | 1927:35 | 108 | 1633:36 | 1637:27 | 108 | C2 |
| C3 | " | " | 20.3 | " | " | 20.3 | C3 |
| C4 | 1934:15 | 1937:44 | 20.7 | 1644:07 | 1647:51 | 20.7 | C4 |
| D1 | " | " | 20.4 | " | " | 20.4 | D1 |
| D2 | 1944:12 | 1948:02 | 20.3 | 1654:18 | 1658:07 | 20.3 | D2 |
| D3 | " | " | 19.0 | " | " | 19.0 | D3 |
| D4 | 1954:40 | 1958:29 | 20.8 | 1704:44 | 1708:28 | 20.8 | D4 |
| E1 | " | " | 19.7 | " | " | 19.7 | E1 |
| E2 | 2005:12 | 2008:39 | 20.7 | 1715:11 | 1718:37 | 20.7 | E2 |
| E3 | " | " | 19.6 | " | " | 19.7 | E3 |
| E4 | 2015:05 | 2018:34 | 20.5 | 1725:02 | 1728:43 | 20.5 | E4 |
| F1 | " | " | 20.2 | " | " | 20.2 | F1 |
| F2 | 2025:04 | 2028:48 | 20.6 | 1735:12 | 1738:41 | 20.6 | F2 |
| F3 | " | " | 19.9 | " | " | 19.9 | F3 |
| F4 | 2035:28 | 2039:12 | 19.9 | 1745:20 | 1748:47 | 19.9 | F4 |

TABLE IX

LP ARRAY SINUSOIDAL CALIBRATIONS (CONCLUDED)

| SUBARRAY | Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude | | | | | | SUBARRAY |
|---|---|---|---|---|---|---|---|
| | Day 051: 20 Feb. 73 | | | Day 057: 26 Feb. 73 | | | |
| | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | Start Time (GMT) | Stop Time (GMT) | Input Ampl. μm P-P | |
| A0 | 1602:13 | 1605:50 | 20.0 | 1600:59 | 1604:41 | 20.0 | A0 |
| C1 | " | " | 19.1 | " | " | 19.2 | C1 |
| C2 | 1612:25 | 1616:02 | 108 | 1611:16 | 1615:04 | 108 | C2 |
| C3 | " | " | 20.4 | " | " | 20.4 | C3 |
| C4 | 1622:42 | 1626:26 | 20.7 | 1621:44 | 1625:27 | 20.7 | C4 |
| D1 | " | " | 20.4 | " | " | 20.4 | D1 |
| D2 | 1632:53 | 1636:26 | 20.3 | 1631:54 | 1635:44 | 20.3 | D2 |
| D3 | " | " | 19.0 | " | " | 19.0 | D3 |
| D4 | 1643:04 | 1646:54 | 20.7 | 1642:21 | 1646:07 | 20.8 | D4 |
| E1 | " | " | 19.7 | " | " | 19.7 | E1 |
| E2 | 1653:37 | 1657:02 | 20.7 | 1652:51 | 1656:15 | 20.7 | E2 |
| E3 | " | " | 19.7 | " | " | 19.7 | E3 |
| E4 | 1703:27 | 1707:00 | 20.5 | 1702:41 | 1706:29 | 20.5 | E4 |
| F1 | " | " | 20.2 | " | " | 20.2 | F1 |
| F2 | 1713:29 | 1717:22 | 20.6 | 1712:58 | 1716:43 | 20.6 | F2 |
| F3 | " | " | 19.9 | " | " | 19.9 | F3 |
| F4 | 1724:01 | 1727:26 | 19.9 | 1723:22 | 1726:57 | 19.9 | F4 |

## TABLE X

## PSEUDO-RANDOM BINARY SEQUENCE SEISMOGRAPH CALIBRATIONS

| System | Date | Approximate Start Time (GMT) | Approximate Stop Time (GMT) | Binary Bit Duration (Sec.) |
|---|---|---|---|---|
| SP | 11 Nov. 72 | 2146 | 2154 | 0.1 |
| SP | 15 Jan. 73 | 1818 | 1826 | 0.1 |
| SP | 15 Feb. 73 | 2107 | 2115 | 0.1 |
| LP | 21 Feb. 73 | 1849 | 1917 | 5.0 |

TABLE XI

INCIDENCE OF DEFECTIVE SUBARRAY CHANNELS

Dec. 1972 - Feb. 1973

| SUBARRAY | CHANNELS | | |
|---|---|---|---|
| | SP | LP | METEOR |
| A0 | 2 | 0 (7) | 0 |
| B1 | 3 | - | - |
| B2 | 7 | - | - |
| B3 | 7 | - | - |
| B4 | 3 | - | - |
| C1 | 0 | 0 (8) | - |
| C2 | 4 | 0 (12) | - |
| C3 | 2 | 0 (17) | - |
| C4 | 3 | 1 (8) | - |
| D1 | 0 | 0 (8) | - |
| D2 | 3 | 1 (16) | - |
| D3 | 2 | 0 (12) | - |
| D4 | 3 | 2 (15) | - |
| E1 | 0 | 0 (13) | 0 |
| E2 | 4 | 0 (11) | 0 |
| E3 | 0 | 3 (10) | - |
| E4 | 3 | 1 (14) | 0 |
| F1 | 8 | 0 (9) | 0 |
| F2 | 1 | 0 (14) | 0 |
| F3 | 3 | 0 (8) | 0 |
| F4 | 2 | 0 (7) | 0 |
| TOTALS | 60 | 8 (189) | 0 |

Defective Signal Channel Status Report is distributed each week to all agencies authorized by VSC. Table XI indicates an incidence of 68 defective channels detected during the three-month period for the three types of array data channels. In addition to the amplitude response tolerances (Table VII) and the LP seismometer positioning tolerances indicated above, the seismograph instrumentation is checked for signal distortion, polarity, offset, and phase.

### 3.3.3 Communications

The interface between array and data center provided by the communications systems plays an important part in the success of the array operation. Determination of data interruptions due to telephone circuit outages is one responsibility of the LDC operations activity. All outages reported by data center personnel are assigned a ticket number to aid in accounting and for identifying of the data interruption. Weekly meetings are held with the telephone company, viz., Mountain Bell and Mid-Rivers, personnel to review and describe all outages.

For the period between 1 December 72 and 28 February 73 the array communications outages were remarkably small (Table XII). Only one exceeded a two-hour duration. This one on 24 February lasted for 6h54m and resulted from wire wrap of the open-wire line near subarray AO.

## 3.4 Logistics

The Government Furnished Property Inventory EDP printout has been upgraded so that each of the approximately 2100 line items is identified individually within the major categories outlined in ASPR "B".

The annual inventory of Material has been completed with no unresolved discrepancies.

TABLE XII

EXTENDED ARRAY DATA INTERRUPTIONS DUE TO COMMUNICATIONS OUTAGES

| DATE | DURATION | SITE | REASON FOR OUTAGE |
|---|---|---|---|
| 2/24/73 | 6:54 | A0 | Wire wrap (open wire near subarray) |

## SECTION IV

## ARRAY PERFORMANCE

### 4.1 Systems

The array's sensing systems include the SP seismograph, the LP seismograph, and the weather sensors. The overall performance measure applied to each of these is array data availability. The percentage of time the array systems are on-line providing quality data determine the value of this measure. Data availabilities are calculated by combining the total subarray data interruption times shown in Table VI with the total sensor outage times reported on the Defective Signal Channel Status reports each week. The data availabilities compared with those of previous periods are shown in Table XIII. The percentage of telephone circuit outages which affect all subarray systems and further reduce the effective system data availabilities are also shown in the table. Accumulating the five quarterly periods of the contract, the SP data availability has been 95.10% and the LP 93.75%; telco outage 0.28%.

### 4.1.1 SP Seismograph

(a) Performance Monitoring Using Program TESP

The results of the computer-controlled sinusoidal calibrations performed this quarter on the 346 short-period seismographs show an average seismograph channel sensitivity of 20.06 mV/nm at a one-second period and an average standard deviation of 1.07 mV/nm. A summary of the test results obtained each week is shown in Table XIV where the statistics are compared with those of the previous contract and those of the previous December-February period. The seismograph calibration responses may be examined from the LASA data recorded at the times indicated in Section III Table IX. The amplitude stability of the SP array is illustrated by the distribution of SP sensors within the ±15% sensitivity tolerance plotted in Figure 4.1. This figure shows the weekly percentage of sensors within this tolerance since 30 March 1970, a 35-month period.

(b) Channel Stability

The individual channel stability of the SP seismograph is measured from a statistical sample of 86 sensors. Six of these sensors were picked at random from subarray E3 and four were randomly sampled from each of the other 20 subarrays. Beginning 1 November 1971, the sensitivities of each of these 86 channels have been obtained from the daily printout of program TESP. At the end of each month a standard deviation of the sensitivity is calculated for each channel. This standard deviation



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TABLE XIII

ARRAY SENSING SYSTEM DATA AVAILABILITIES

| PERIOD | % DATA AVAILABILITY | | | % OUTAGE |
|---|---|---|---|---|
| | SP | LP | MET | TELCO |
| 12/72 - 2/73 | 98.0 | 92.6 | 99.8 | 0.03 |
| 9/72 - 11/72 | 94.6 | 91.4 | 99.7 | 0.11 |
| 6/72 - 8/72 | 94.3 | 94.9 | 99.2 | 0.52 |
| 3/72 - 5/72 | 95.4 | 97.4 | 98.9 | 0.23 |
| 12/72 - 2/72 | 93.3 | 93.2 | 100.0 | 0.50 |
| 12/71 - 11/72 | 96.7 | 98.6 | 99.2 | 0.45 |

TABLE XIV

SP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

| DATE | NO. SENSORS | SENS. MEAN mV/nm | SENS. $\sigma$ mV/nm | SENS. MAX. mV/nm | SENS. MIN. mV/nm | SENS. DEV. mV/nm |
|---|---|---|---|---|---|---|
| 12/4 | 345 | 20.03 | 1.19 | 23.09 | 15.90 | 7.19 |
| 12/11 | 345 | 19.76 | 1.34 | 23.19 | 14.41 | 8.78 |
| 12/18 | 344 | 20.07 | 1.20 | 24.13 | 13.14 | 10.99 |
| 12/25 | 344 | 20.06 | 1.06 | 23.23 | 12.41 | 10.82 |
| 1/1 | 345 | 20.04 | 1.09 | 22.95 | 14.46 | 8.49 |
| 1/8 | 345 | 19.59 | 1.37 | 23.23 | 14.25 | 8.98 |
| 1/15 | 342 | 20.17 | 1.01 | 24.30 | 12.13 | 12.17 |
| 1/22 | 344 | 20.05 | 0.98 | 23.44 | 16.54 | 6.90 |
| 1/29 | 344 | 20.03 | 0.99 | 23.65 | 16.09 | 7.56 |
| 2/5 | 345 | 20.18 | 0.97 | 24.60 | 17.39 | 7.21 |
| 2/12 | 346 | 20.08 | 1.06 | 24.95 | 16.37 | 8.58 |
| 2/20 | 345 | 20.15 | 0.92 | 24.09 | 17.26 | 6.83 |
| 2/26 | 345 | 20.12 | 0.79 | 22.64 | 16.65 | 5.99 |
| AVERAGE | 344.54 | 20.06 | 1.07 | 23.65 | 15.15 | 8.50 |
| PREVIOUS DEC-FEB AVERAGE | 343.23 | 20.20 | 1.58 | 23.48 | 14.45 | 9.04 |
| CONTRACT AVERAGE | 336.56 | 20.30 | 1.29 | 24.03 | 13.17 | 11.01 |
| PREVIOUS CONTRACT AVERAGE | 343.9 | 20.36 | 1.69 | 26.5 | 12.7 | 13.8 |

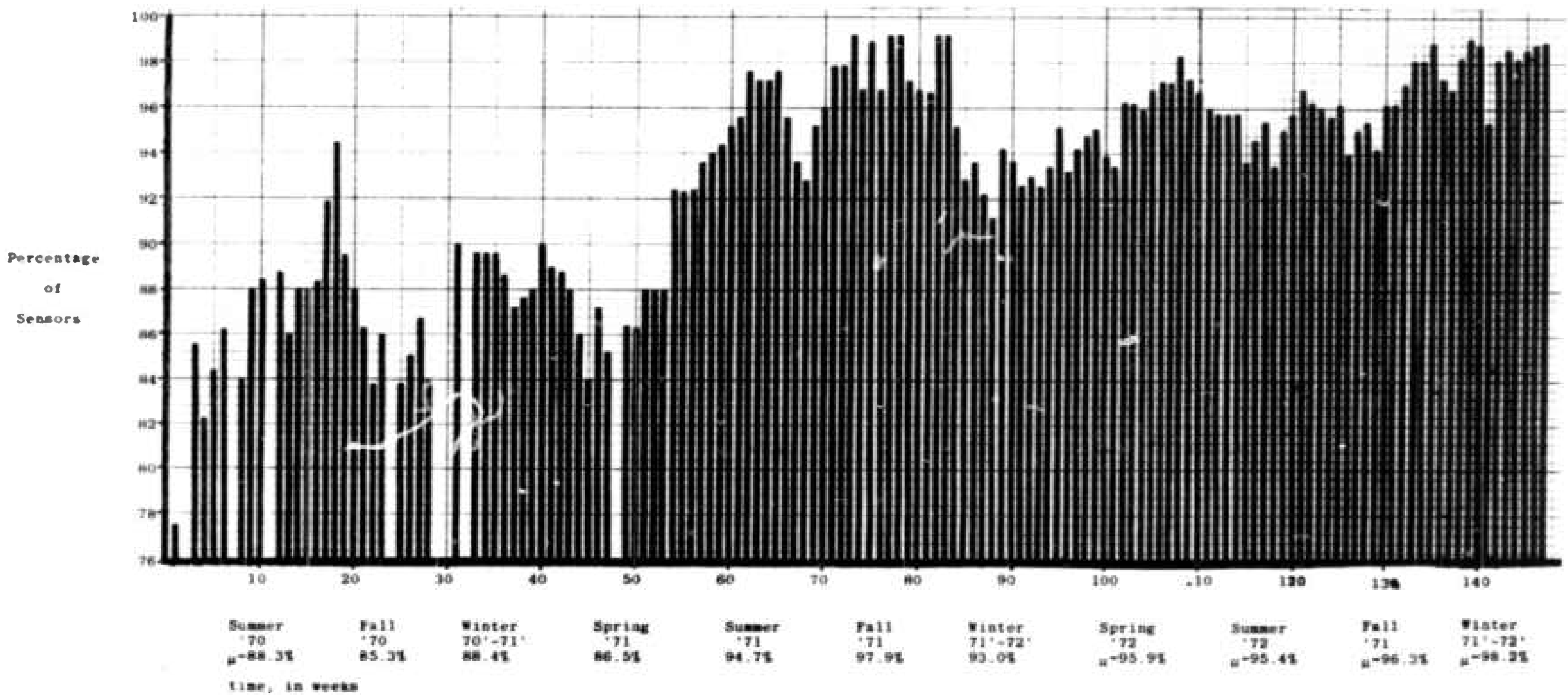


Figure 4.1 Percentage Distribution of SP Sensors Within the ±15% Sensitivity Tolerance

value is used as a comparative measure of the individual channel stability. Table XV shows the results from 14 months use of this statistic.

Assuming the distribution of an individual channel's sensitivity is normal or an approximate normal distribution, Table XV shows that for a large majority of SP seismographs the measured sensitivity can be expected to be within 1 mV/nm of the instrument's mean sensitivity.

During December 1972, an extended period (Dec. 4-14) of extremely cold temperatures occurred across the array. Then a warming period (Dec. 16-28) of above freezing temperatures developed. These temperature extremes affect the output of the SP seismographs so that an increase in the sensitivity standard deviation of each channel is observed. The increase and decrease in the percentage of channels with a standard deviation less than 0.33 mV/nm appears to be indicative of this type of environmental stress on the SP channels WHV amplifier, the RA-5.

(c) Channel Frequency Response

The measured channel frequency response is shown in Figure 4.2 where the mean, the minimum, and the maximum response curves of the array as measured during the period 19 May 70 (B2) through 6 November 72 (B1) are plotted. Table XVI shows the average and the standard deviation of the channel sensitivities for each of the 16 frequencies used in the measurement.

### 4.1.2 LP Seismograph

(a) Performance Monitoring Using Program TELP

The computer controlled sinusoidal calibrations performed this quarter on the 45 standard response long-period seismographs resulted in an average channel sensitivity of 361.97 mV/$\mu$m at a 25 second period and an average standard deviation of 24.67 mV/$\mu$m. The weekly test results obtained are shown in Table XVII where this quarter's statistics may be compared with those of previous periods. The times associated with these calibration tests were shown previously in Section III, Table X.

The percentage distribution of the 45 LP sensors within the 350 $\pm$ 50 mV/$\mu$m sensitivity calibration tolerance throughout the 27-month period starting 8 December 70 through 26 February 73 is plotted in Figure 4.3. The dip in the plot which occurred during this quarter is attributed to a high level of moisture present in the LP seismometer tanks at several subarrays, viz., D4, E2, and E4. The measured sensitivity appears to be affected by crosstalk between the high-level calibration signal line and the seismometer output signal line. Whether or not the seismic signals were influenced to the same extent during this period is not known.

TABLE XV

A DISTRIBUTION OF THE STANDARD DEVIATIONS OF 86 LASA SP CHANNELS

| | MEAN S In mV/nm | MAXIMUM S In mV/nm | MINIMUM S In mV/nm | % <.3333 mV/nm |
|---|---|---|---|---|
| Nov. 71 | 0.1831 | 1.072 | 0.0570 | 95.3 |
| Dec. 71 | 0.2236 | 1.945 | 0.0277 | 86.0 |
| Jan. 72 | 0.2902 | 1.306 | 0.0807 | 73.3 |
| Feb. 72 | 0.2559 | 1.690 | 0.0630 | 80.2 |
| Mar. 72 | 0.3075 | 2.050 | 0.0849 | 70.6 |
| Apr. 72 | 0.2030 | 3.007 | 0.0415 | 93.0 |
| May 72 | 0.2629 | 1.025 | 0.0625 | 79.1 |
| Jun. 72 | 0.2190 | 1.582 | 0.0370 | 91.9 |
| Jul. 72 | 0.2613 | 1.348 | 0.0640 | 83.7 |
| Aug. 72 | 0.2335 | 0.7292 | 0.0372 | 90.7 |
| Sep. 72 | 0.3022 | 0.9937 | 0.0809 | 73.3 |
| Oct. 72 | 0.2350 | 0.9708 | 0.0480 | 88.2 |
| Nov. 72 | 0.1559 | 0.6781 | 0.0510 | 95.3 |
| Dec. 72 | 0.3004 | 1.3650 | 0.0517 | 63.5 |

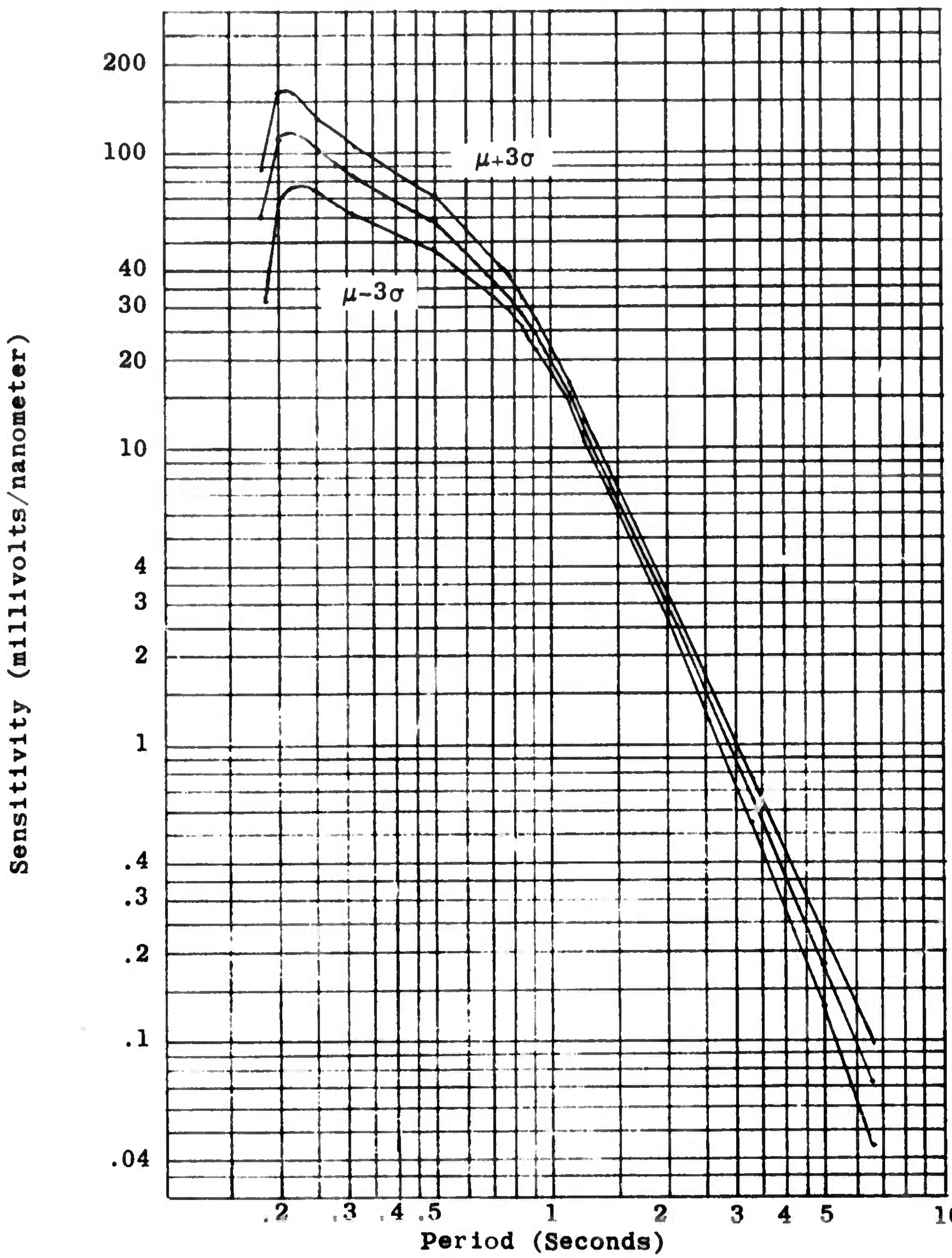


Figure 4.2 LASA SP Sensor Period vs Sensitivity Response Curves

TABLE XVI

SEISMOGRAPH FREQUENCY RESPONSE OF SP ARRAY

| FREQUENCY (HERTZ) | SEISMOGRAPH CHANNEL SENSITIVITY (MV/NM) NO. CHANNELS = 337 | | |
|---|---|---|---|
| | MEAN | STANDARD DEVIATION | MAXIMUM DEVIATION |
| 0.15 | 0.071 | 0.009 | 0.034 |
| 0.20 | 0.184 | 0.017 | 0.067 |
| 0.30 | 0.659 | 0.037 | 0.135 |
| 0.50 | 3.07 | 0.116 | 0.460 |
| 0.70 | 7.99 | 0.253 | 1.07 |
| 0.80 | 11.5 | 0.38 | 1.40 |
| 0.90 | 15.6 | 0.50 | 1.70 |
| 1.0 | 19.8 | 0.69 | 2.50 |
| 1.1 | 24.3 | 0.90 | 3.30 |
| 1.2 | 28.7 | 1.17 | 4.50 |
| 1.3 | 32.9 | 1.47 | 6.00 |
| 2.0 | 59.5 | 3.87 | 17.0 |
| 3.0 | 82.4 | 7.11 | 31.9 |
| 4.0 | 104.0 | 9.8 | 39.2 |
| 5.0 | 118.0 | 16.6 | 59.1 |
| 6.0 | 60.3 | 9.76 | 35.7 |

TABLE XVII

LP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

| DATE | NO. SENSORS | SENS. MEAN mV/$\mu$m | SENS. $\sigma$ mV/$\mu$m | SENS. MAX. mV/$\mu$m | SENS. MIN. mV/$\mu$m | SENS. DEV. mV/$\mu$m |
|---|---|---|---|---|---|---|
| 12/4 | 45 | 355.5 | 25.6 | 440.6 | 319.3 | 121.2 |
| 12/11 | 45 | 361.0 | 22.0 | 430.4 | 318.1 | 112.3 |
| 12/18 | 44 | 360.2 | 21.6 | 412.2 | 316.9 | 95.3 |
| 12/25 | 45 | 361.6 | 23.0 | 420.0 | 318.0 | 104.0 |
| 1/1 | 44 | 366.6 | 28.0 | 443.5 | 320.1 | 123.4 |
| 1/8 | 43 | 369.3 | 28.4 | 453.2 | 324.0 | 129.2 |
| 1/15 | 44 | 369.0 | 28.0 | 448.9 | 323.8 | 125.2 |
| 1/22 | 42 | 367.8 | 38.1 | 446.4 | 320.0 | 126.4 |
| 1/29 | 44 | 358.3 | 21.0 | 450.5 | 322.0 | 128.5 |
| 2/5 | 44 | 362.2 | 22.4 | 459.1 | 321.5 | 137.6 |
| 2/12 | 43 | 359.9 | 18.2 | 487.6 | 319.4 | 168.2 |
| 2/20 | 44 | 359.8 | 23.2 | 452.4 | 315.1 | 137.3 |
| 2/26 | 45 | 354.5 | 21.2 | 399.5 | 268.1 | 131.4 |
| AVERAGE | 44.0 | 362.0 | 24.7 | 434.3 | 315.9 | 126.2 |
| PREVIOUS DEC-FEB AVERAGE | 44.9 | 367.6 | 17.8 | 418.5 | 330.8 | 87.7 |
| CONTRACT AVERAGE | 44.4 | 354.3 | 19.0 | 404.5 | 308.1 | 99.1 |
| PREVIOUS CONTRACT AVERAGE | 44.6 | 356.1 | 18.8 | 403.0 | 312.0 | 90.0 |

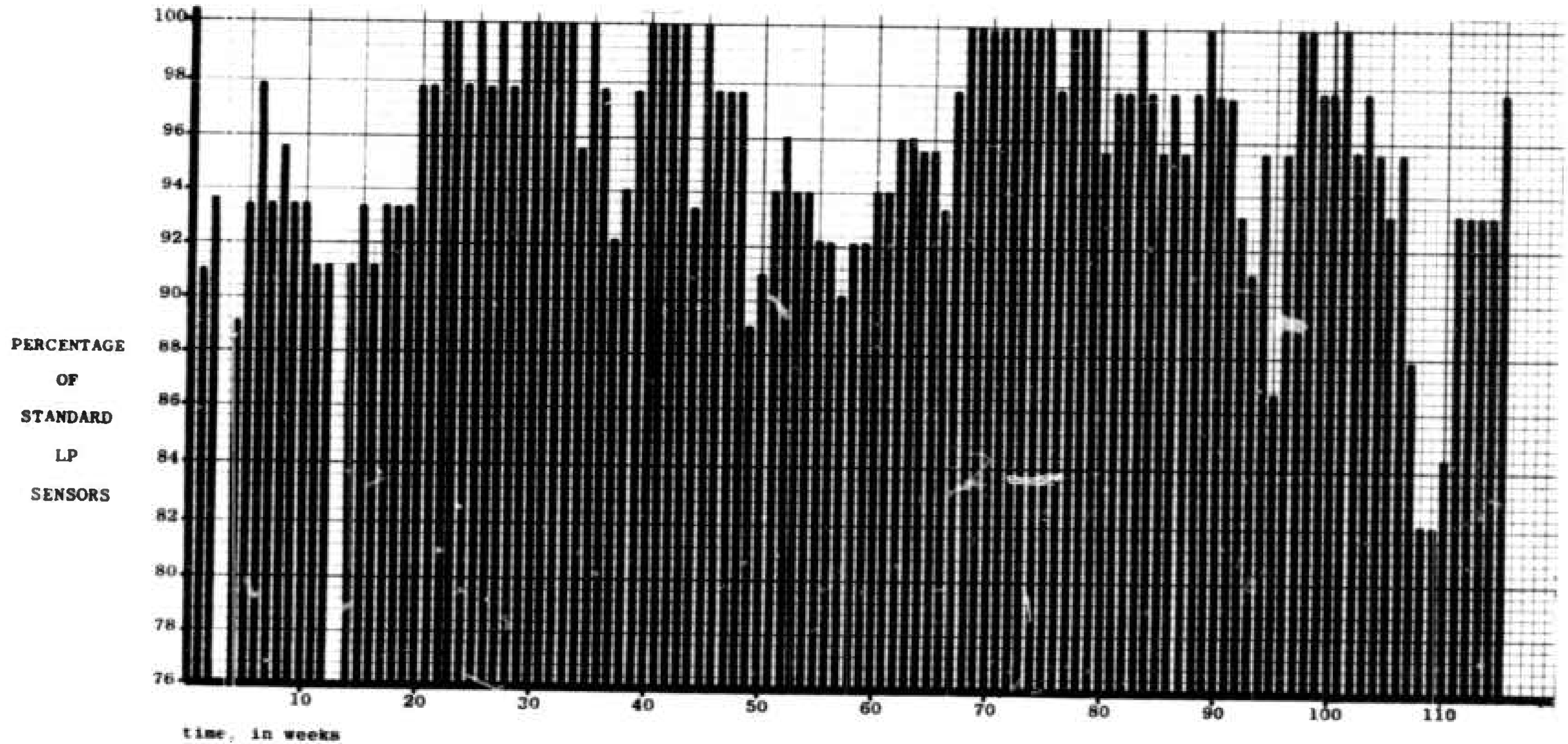


Figure 4.3 Percentage Distribution of LP Sensors Within The ±50 mV/μm Sensitivity Tolerance

(b) Free Period/Mass Position Measurements

The free period and mass position of each of the 51 long-period seismometers are measured remotely each week at the LDC. The array summaries from these tests are shown in Table XVIII. These data indicate the average free period across the array over the thirteen-week quarter to be 20.02 sec/cycle with an average weekly variation of 0.01 sec/cycle. Instruments are readjusted if the free period exceeds 20 ± 1 second. The forty-two adjustments maintained the array at the values shown in the table.

Mass position centering averaged -0.19 mm while the average weekly variation measured | 0.12 | mm. These figures summarize the complete array measurements and are being studied to help determine the effectiveness of the present tolerances, viz. mass position within ± 1.4 mm of center. An average of 11.5 adjustments each week this quarter were necessary to maintain the 51 instrument masses within this range.

## 4.2 Surficial Noise Investigation

Oil exploration drilling occurred at the following five locations in the array:

1. NWNW Sec. 17 16N41E approximately 15 miles from sensor 81, subarray D4 (now plugged and abandoned).
2. NESW Sec. 27 2N45E approximately 16 miles from sensor 84, subarray E3.
3. SESW Sec. 22 2N45E approximately 13 miles from sensor 84, subarray E3.
4. NENE Sec. 26 3N47E approximately 16 miles from sensor 76, subarray F2 (now plugged and abandoned).
5. SWNW Sec. 32 1N48E approximately 14 miles from sensor 85, subarray F2.

## 4.3 Failure Report

The array system and equipment failures which occurred and/or were corrected are reported in this section. All the failures are classified according to the type of failure and include these five classifications:

(1) System failure - A failure resulting in zero or no system output which prevents the system or equipment assembly from performing its primary function and identified as a Type 1 failure.

TABLE XVIII

LP ARRAY SEISMOGRAPH FREE PERIOD/MASS POSITION MEASUREMENT SUMMARY

| Test Date | Free Period, Sec/Cycle | | | No. Free Period Adjusts | Mass Position, mm | | | No. Mass Position Adjusts |
|---|---|---|---|---|---|---|---|---|
| | Average Before Adjusts | Average After Adjusts | Weekly Variation | | Average Before Adjusts | Average After Adjusts | Weekly Variation | |
| 11/27 | 20.00 | 19.97 | - | - | -0.37 | -0.15 | - | - |
| 12/4 | 19.92 | 19.92 | -0.05 | 2 | -0.15 | -0.21 | 0.00 | 10 |
| 12/11 | 19.97 | 19.98 | +0.05 | 4 | -0.17 | -0.09 | +0.04 | 21 |
| 12/18 | 19.88 | 19.89 | -0.10 | 2 | -0.18 | -0.06 | -0.09 | 15 |
| 12/26 | 19.97 | 19.94 | +0.08 | 1 | -0.16 | -0.04 | -0.10 | 11 |
| 1/3 | 19.89 | 19.93 | -0.05 | 3 | -0.20 | -0.12 | -0.16 | 7 |
| 1/8 | 19.88 | 19.95 | -0.05 | 5 | -0.23 | -0.20 | -0.11 | 11 |
| 1/15 | 20.04 | 20.05 | +0.09 | 2 | -0.30 | -0.02 | -0.10 | 17 |
| 1/22 | 19.93 | 19.97 | -0.12 | 2 | -0.43 | -0.25 | -0.41 | 9 |
| 1/29 | 20.00 | 20.05 | +0.03 | 2 | -0.08 | -0.08 | +0.17 | 8 |
| 2/5 | 20.43 | 20.20 | +0.38 | 11 | -0.27 | -0.11 | -0.19 | 15 |
| 2/12 | 20.19 | 20.17 | -0.01 | 1 | -0.22 | -0.13 | -0.11 | 10 |
| 2/20 | 20.12 | 20.07 | -0.05 | 5 | -0.07 | -0.03 | +0.06 | 6 |
| 2/26 | 20.00 | 20.04 | -0.07 | 2 | -0.05 | -0.06 | -0.02 | 9 |

(2) Mode failure - A failure resulting in a zero or no system output only during one of several different modes of operation; a Type 2 failure.

(3) Limited failure - A failure resulting in a system output which is outside the allowable tolerance limits but permits degraded performance; a Type 3 failure.

(4) Latent failure - A failure which changes a system output either by an amount less than the allowable tolerance or from the nominal output when no tolerance limits have been established; a Type 4 failure.

(5) Temporary failure - A failure produced by an operating or environmental stress which results in no permanent physical damage; a Type 5 failure.

The number of failures detected and corrected in each of the ten Montana array systems is shown in Table XIX. The backlog of system or operating unit failures has decreased to 3. The PDP-7 computer, the SEM, and the LDC Test and Support systems were the chief contributors (65%) of the failures.

The distribution of the equipment failures resulting from the system failures is shown in Table XX. Since more than one equipment failure may sometimes occur with a system failure, the number of equipment failures corrected may exceed the number of system failures reported.

Equipment failure rates for the array equipment have been determined for the period beginning May 1968. These average monthly failure rates have been totalled to determine a significant parameter for planning purposes, the system failure rate. Table XXI compares these average failure rates calculated since the beginning of this contract period (December 1971) with the historical rate. Summing the rates of the ten systems shows the average monthly failure rate for all of the array's equipment to be 47.95 failures/month; the figure for the contract period only is 48.67.

TABLE XIX

LASA SYSTEM FAILURE DETECTIONS AND CORRECTIONS

DECEMBER 1972 - FEBRUARY 1973

| | STARTING BACKLOG | DETECTED | CORRECTED | ENDING BACKLOG |
|---|---|---|---|---|
| SP SENSOR | 5 | 15 | 20 | 0 |
| LP SENSOR | 1 | 8 | 8 | 1 |
| METEOROLOGICAL SYSTEM | 0 | 0 | 0 | 0 |
| SEM | 2 | 24 | 26 | 0 |
| POWER SYSTEM | 0 | 3 | 3 | 0 |
| 360 COMPUTER | 0 | 4 | 4 | 0 |
| PDP-7 COMPUTER | 1 | 34 | 34 | 1 |
| LDC DIGITAL | 0 | 2 | 2 | 0 |
| LDC ANALOG | 0 | 12 | 12 | 0 |
| LDC TEST AND SUPPORT | 0 | 24 | 23 | 1 |
| TOTALS | 9 | 126 | 132 | 3 |

TABLE XX

EQUIPMENT FAILURES

| ARRAY SYSTEM/EQUIPMENT | NUMBER OF FAILURES | | | | | |
|---|---|---|---|---|---|---|
| | TYPE OF FAILURE | | | | | |
| | 1 | 2 | 3 | 4 | 5 | TOTAL |
| Short-Period System | | | | | | |
| Seismometer | 2 | 0 | 0 | 0 | 1 | 3 |
| WHV Panel W/RA-5 | 4 | 0 | 13 | 0 | 0 | 17 |
| WHV/Cables | 1 | 0 | 0 | 0 | 0 | 1 |
| Total | 7 | 0 | 13 | 0 | 1 | 21 |
| Long-Period System | | | | | | |
| Vertical Seismometer/Tank | 1 | 0 | 1 | 0 | 0 | 2 |
| Seismic Amplifier, Type II | 0 | 0 | 4 | 1 | 1 | 6 |
| Total | 1 | 0 | 5 | 1 | 1 | 8 |
| Meteorological System | | | | | | |
| Total | 0 | 0 | 0 | 0 | 0 | 0 |
| Subarray Electronics Modules | | | | | | |
| Input Drawer #1 | 0 | 0 | 0 | 21 | 0 | 21 |
| Input Drawer #2 | 0 | 0 | 1 | 21 | 0 | 22 |
| Multiplexer/ADC | 1 | 0 | 0 | 0 | 0 | 1 |
| PDC Drawer | 1 | 0 | 2 | 0 | 0 | 3 |
| Total | 2 | 0 | 3 | 42 | 0 | 47 |
| Power System | | | | | | |
| Control Drawer | 0 | 0 | 1 | 0 | 0 | 1 |
| Inverter | 2 | 0 | 0 | 0 | 0 | 2 |
| Total | 2 | 0 | 1 | 0 | 0 | 3 |
| 360 System | | | | | | |
| CPU 2044 | 0 | 0 | 0 | 0 | 1 | 1 |
| Data Adapter 1827 | 1 | 0 | 0 | 0 | 0 | 1 |
| Total | 2 | 0 | 1 | 0 | 1 | 4 |

TABLE XX

EQUIPMENT FAILURES (CONCLUDED)

| ARRAY SYSTEM/EQUIPMENT | NUMBER OF FAILURES | | | | | |
|---|---|---|---|---|---|---|
| | TYPE OF FAILURE | | | | | TOTAL |
| | 1 | 2 | 3 | 4 | 5 | |
| PDP-7 System | | | | | | |
| Computer | 1 | 0 | 1 | 0 | 1 | 3 |
| Teletypewriter KSR-35 | 1 | 0 | 1 | 2 | 0 | 4 |
| Card Reader | 1 | 0 | 2 | 0 | 0 | 3 |
| Tape Unit #19 | 0 | 0 | 2 | 0 | 0 | 2 |
| Tape Unit #32 | 1 | 0 | 7 | 0 | 1 | 9 |
| Tape Unit #33 | 2 | 0 | 2 | 0 | 1 | 5 |
| Tape Unit #22 | 2 | 0 | 6 | 0 | 0 | 8 |
| Total | 8 | 0 | 21 | 2 | 3 | 34 |
| Digital System | | | | | | |
| Timing System #2 | 0 | 0 | 1 | 0 | 0 | 1 |
| MINS | 1 | 0 | 0 | 0 | 0 | 1 |
| Total | 1 | 0 | 1 | 0 | 0 | 2 |
| Analog System | | | | | | |
| D/A Patch Panel Cabinet | 0 | 0 | 1 | 0 | 0 | 1 |
| WWV Receiver | 1 | 0 | 0 | 0 | 0 | 1 |
| Analog Timing System | 0 | 0 | 1 | 0 | 0 | 1 |
| Develocorder #147 | 0 | 0 | 2 | 0 | 0 | 2 |
| Develocorder #150 | 0 | 1 | 3 | 1 | 2 | 7 |
| Total | 1 | 1 | 7 | 1 | 2 | 12 |
| LDC Test and Support System | | | | | | |
| MDC-1 | 1 | 0 | 13 | 0 | 1 | 15 |
| MDC-2 | 0 | 0 | 9 | 0 | 0 | 9 |
| Film Viewer | 2 | 0 | 0 | 0 | 0 | 2 |
| Total | 3 | 0 | 22 | 0 | 1 | 26 |

TABLE XXI

EQUIPMENT FAILURE RATES

| ARRAY SYSTEM/EQUIPMENT | MONTHLY FAILURE RATES SINCE 12/71 | SINCE 5/68 |
|---|---|---|
| Short-Period System | 15.73 | 15.43 |
| Seismometer | 3.40 | 1.23 |
| WHV Panel W/RA-5 | 11.60 | 13.55 |
| RA-5 Power Supply | 0.27 | 0.23 |
| WHV Junction Box | 0.00 | 0.09 |
| WHV/Cables | 0.13 | 0.16 |
| CTH Junction Box (SP) | 0.33 | 0.16 |
| Long-Period System | 1.60 | 2.70 |
| Vertical Seismometer/Tank | 0.13 | 0.12 (1) |
| Horizontal Seismometer/Tank | 0.20 | 0.12 (1) |
| LP Vault/Cabling | 0.00 | 0.18 (1) |
| LP Junction Assembly | 0.00 | 0.32 (1) |
| Motor Assembly | 0.26 | 0.26 (1) |
| Seismic Amplifier, Type II | 0.93 | 0.91 (1) |
| Amplifier Power Supply | 0.00 | 0.06 (1) |
| CTH Junction Box (LP) | 0.07 | 0.24 (1) |
| Meteorological System | 0.13 | 0.18 |
| Aerovane, Wind Direction | 0.00 | 0.07 (2) |
| Aerovane, Wind Speed | 0.00 | 0.02 (2) |
| Pole Assembly | 0.00 | 0.00 (2) |
| Pole Junction Box/Cabling | 0.00 | 0.00 (2) |
| Temperature Probe | 0.07 | 0.07 (2) |
| Electrobarometer/Baffle | 0.00 | 0.00 (2) |
| Rain Gauge | 0.00 | 0.00 (2) |
| Rain Gauge Electronics Panel | 0.07 | 0.02 (2) |
| Subarray Electronics Modules | 5.27 | 6.14 |
| Input Drawer #1 | | |
| Input Drawer #2 | 3.47 | 2.70 |
| Multiplexer/ADC | 0.13 | 0.43 |
| Output Drawer | 0.60 | 0.61 |
| PDC Drawer | 0.87 | 2.29 |
| ACC Cabinet | 0.20 | 0.11 |
| SEM Cabinet/Cabling | 0.00 | 0.02 |
| Alarms | 0.00 | 0.00 |

TABLE XXI

EQUIPMENT FAILURE RATES (CONTINUED)

<table>
<tr><th rowspan="2">ARRAY SYSTEM/EQUIPMENT</th><th colspan="2">MONTHLY FAILURE RATES</th></tr>
<tr><th>SINCE 12/71</th><th>SINCE 5/68</th></tr>
<tr><td>Power System</td><td>1.53</td><td>1.38</td></tr>
<tr><td>Control Drawer</td><td>0.47</td><td>0.61</td></tr>
<tr><td>Inverter</td><td>1.07</td><td>0.59</td></tr>
<tr><td>Charger</td><td>0.00</td><td>0.14</td></tr>
<tr><td>Battery</td><td>0.00</td><td>0.00</td></tr>
<tr><td>SOLA Transformer</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Rack Cabling</td><td>0.00</td><td>0.02</td></tr>
<tr><td>Isolation Transformer</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Breaker Panel</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Vault/Wiring/Breakers/Outlets</td><td>0.00</td><td>0.02</td></tr>
<tr><td>360 System</td><td>1.00</td><td>1.71</td></tr>
<tr><td>CPU 2044</td><td>0.13</td><td>0.75</td></tr>
<tr><td>Disc Drive 2315</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Typewriter 1052</td><td>0.67</td><td>0.64</td></tr>
<tr><td>Card Reader 2501</td><td>0.00</td><td>0.13</td></tr>
<tr><td>Data Control 1826</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Data Adapter 1827</td><td>0.07</td><td>0.07</td></tr>
<tr><td>Data Adapter 2701</td><td>0.13</td><td>0.13</td></tr>
<tr><td>PDP-7 System</td><td>12.67</td><td>12.64</td></tr>
<tr><td>Computer</td><td>1.40</td><td>1.11</td></tr>
<tr><td>Teletypewriter KSR-35</td><td>0.60</td><td>0.54</td></tr>
<tr><td>Card Reader</td><td>1.00</td><td>0.98</td></tr>
<tr><td>SOU</td><td>0.00</td><td>0.05</td></tr>
<tr><td>Interface</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Tape Unit #19</td><td>1.40</td><td rowspan="4">8.14 (2)</td></tr>
<tr><td>Tape Unit #32</td><td>3.13</td></tr>
<tr><td>Tape Unit #33</td><td>2.73</td></tr>
<tr><td>Tape Unit #22</td><td>2.33</td></tr>
<tr><td>Incremental Recorder</td><td>0.07</td><td>0.29</td></tr>
<tr><td>Digital System</td><td>0.93</td><td>0.52</td></tr>
<tr><td>Timing System #1</td><td>0.40</td><td rowspan="3">0.34</td></tr>
<tr><td>Timing System #2</td><td>0.27</td></tr>
<tr><td>Digital Data Simulator</td><td>0.00</td></tr>
<tr><td>Power System</td><td>0.07</td><td>0.02</td></tr>
<tr><td>PLINS</td><td>0.07</td><td>0.07</td></tr>
<tr><td>MINS</td><td>0.13</td><td>0.09</td></tr>
</table>

TABLE XXI

EQUIPMENT FAILURE RATES (CONCLUDED)

| ARRAY SYSTEM/EQUIPMENT | MONTHLY FAILURE RATES SINCE 12/71 | SINCE 5/68 |
|---|---|---|
| Analog System | 3.00 | 2.21 |
| D/A Patch Panel Cabinet | | |
| D/A Converter #1 | | |
| D/A Converter #2 | 0.07 | 0.32 |
| D/A Converter #3 | | |
| D/A Converter #4 | | |
| FM System | 0.00 | 0.07 (3) |
| 16 Channel Chart Recorder | 0.13 | 0.48 (3) |
| WHV Receiver | 0.07 | 0.19 (3) |
| Analog Calibration System | 0.00 | 0.00 (3) |
| Analog Timing System | 0.40 | 0.33 (3) |
| SP Develocorder | 0.73 | 1.38 |
| LP Develocorder | 1.60 | |
| LDC Test and Support System | 7.00 | 5.04 |
| MDC-1 | 4.27 | 4.80 |
| MDC-2 | 2.33 | |
| Clocks | 0.00 | 0.00 (3) |
| Film Viewer | 0.20 | 0.15 (3) |
| Film Duplicator | 0.00 | 0.00 (3) |
| Copier | 0.07 | 0.04 (3) |
| Emergency Lights | 0.00 | 0.04 (3) |
| Compressor, Blower | 0.00 | 0.07 (3) |
| Digital Clocks | 0.00 | 0.04 (3) |
| Air Conditioners | 0.07 | 0.11 (3) |
| Humidifier | 0.00 | 0.00 (3) |
| Tape Cleaner | 0.07 | 0.04 (3) |
| Electrostatic Filters | 0.00 | 0.00 (3) |

Notes: 1. Monthly failure rates since 5/70 and not 5/68.
2. Monthly failure rates since 7/69 and not 5/68.
3. Monthly failure rates since 12/70 and not 5/68.

## SECTION V

## IMPROVEMENTS AND MODIFICATIONS

### 5.1 General

Important to the operation of the Montana LASA is the continuing incorporation of improvements and modifications into the various equipments. These improvements permit increased efficiency in the utilization, operation and maintenance of the seismic observatory's systems. The improvements reported this quarter are in the area of PDP-7 programming. Improvements in the PDP-7 programming result in more efficient operation and increase the data collection capability of the array performance measurement activity.

### 5.2 PDP-7 Programming

Programming effort for this period consentrated on the broadband calibration analysis programs BASP and BALP.

#### 5.2.1 BASP

Program BASP (Ref. 5) has been improved to provide broadband sensitivity calibration of the SP seismograph channels as well as gain and phase. BASP processes the seismograph output responses from the SP PRBS calibration input. The program now determines the seismograph parameters of gain, phase, and sensitivity for any selected harmonic of the fundamental frequency of the PRBS as shown in the sample output in Figure 5.1. N is the harmonic of the fundamental frequency, 0.0787 hertz. The gain values are in dB with respect to the reference signal amplitude measured on SEM channel 30, the phase is in degrees, and the sensitivity is in mV/nm.

#### 5.2.2 BALP

Program BALP, similar to program BASP, processes the LP seismograph output responses from the LP PRBS calibrations to provide a broadband measurement of the LP seismograph gain, phase, and sensitivity. The mathematical development and program description is reported in Reference 6.

The seismograph responses are collected by the PDP-7 computer on high-rate formatted digital magnetic tape recordings. These recordings are then later processed with the array data off-line from the computer using program BALP. The program transforms the time series data into the frequency domain by computing the harmonic content at each sample time during PRBS period. These harmonic components, collected from the 254 data samples, determine the amplitude and phase response of each seismograph



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```
I HAVE THE FOLLOWING CALCULATIONS FOR SENSOR U1 0110
FOR DATA RECORDED ON DAY 046 AT APROX 2100 HOURS.

DC VALUE FOR DATA SIG                 -7.98425
SUM VALUE FOR DATA SIG            563692.00000
DC VALUE FOR REF SIG                -141.52362
SUM VALUE FOR REF SIG            1488423.00000
```

| N | GAIN | PHASE | SENSITIVITY |
|---|---|---|---|
| 1 | -31.51700 | 162.05939 | .00731 |
| 2 | -23.87380 | -108.64884 | .07051 |
| 3 | -18.58210 | -97.72482 | .29177 |
| 4 | -15.92530 | -110.05316 | .70430 |
| 5 | -14.11690 | -40.29325 | 1.35520 |
| 6 | -12.46990 | -9.85372 | 2.35883 |
| 7 | -11.11260 | -52.88343 | 3.75391 |
| 8 | -9.70150 | -22.89997 | 5.76785 |
| 9 | -8.75590 | 27.57760 | 8.13943 |
| 10 | -8.13290 | -43.85247 | 10.79645 |
| 11 | -7.33530 | 48.28487 | 14.32038 |
| 12 | -7.18430 | -14.11309 | 17.34146 |
| 13 | -6.89740 | -6.35352 | 21.03516 |
| 14 | -7.21510 | 32.13663 | 23.52019 |
| 15 | -6.90500 | 37.26574 | 27.98170 |
| 16 | -7.33280 | 61.41935 | 30.30639 |
| 17 | -7.22060 | 111.89006 | 34.65791 |
| 18 | -7.97110 | 111.18131 | 35.63774 |
| 19 | -7.93840 | 86.24504 | 39.85730 |
| 20 | -8.20790 | 129.05244 | 42.81354 |
| 21 | -8.20700 | 129.48158 | 47.20739 |
| 22 | -8.93250 | 130.48770 | 47.65680 |
| 23 | -9.02550 | 70.82274 | 51.53231 |
| 24 | -9.70080 | 157.38119 | 51.91424 |
| 25 | -9.65160 | 171.95151 | 56.65092 |
| 26 | -10.28770 | 164.43315 | 56.94725 |
| 27 | -10.43090 | 151.12449 | 60.40962 |
| 28 | -10.92450 | 112.23154 | 61.37862 |
| 29 | -10.83830 | -166.65508 | 66.49745 |
| 30 | -11.29340 | 116.65821 | 67.52931 |
| 31 | -11.54380 | 163.62070 | 70.05717 |
| 32 | -11.89130 | 140.09906 | 71.72116 |
| 33 | -12.28520 | -150.14531 | 72.88934 |
| 34 | -12.61630 | -170.14325 | 74.47748 |
| 35 | -13.41090 | 158.04697 | 72.02576 |
| 36 | -13.16320 | -171.57679 | 78.40385 |
| 37 | -13.87150 | -151.84413 | 76.33747 |
| 38 | -13.81820 | 162.78762 | 81.01374 |
| 39 | -14.20130 | -173.74085 | 81.65244 |
| 40 | -14.38760 | -155.10254 | 84.07487 |

Figure 5.1 Program BASP Printout of SP Seismograph Responses Between 0.078 and 3.15 Hertz

channel. By comparing the responses from each channel to the seismometer input signal as measured remotely from the reference channel, the seismograph parameters of gain, phase, and sensitivity for any selected harmonic of the fundamental frequency can be determined. The fundamental frequency ($\frac{1}{127t}$) depends upon the bit width (t) in the LP PRBS which is variable for the LP system calibrations.

A typical LP seismograph BALP printout is shown in Figure 5.2. Here the bit width (t) was set equal to 5 seconds so that the fundamental frequency is 0.00157 hertz. The responses were determined over the harmonic range of N from 8 to 38, corresponding to a period range of 79.4 to 16.7 seconds/cycle. The broadband response measurements from the first run of this program are provided in Reference 7.

I HAVE THE FOLLOWING CALCULATIONS FOR SENSOR E2 2611
FOR DATA RECORDED ON DAY 052 AT APROX 1900 HOURS.

DC V0LUE FOR DATA SIG -.55511
SUM VALUE FOR DATA SIG 449273.00000
DC VALUE FOR REF SIG 4126.35826
SUM VALUE FOR REF SIG 1048847.00000

| N | GAIN | PHASE | SENSITIVITY |
|---|---|---|---|
| 8 | -10.57050 | -22.89940 | 26.18676 |
| 9 | -9.25830 | -62.42604 | 38.54639 |
| 10 | -8.21950 | -43.81179 | 53.63475 |
| 11 | -7.28670 | -41.69643 | 72.25958 |
| 12 | -6.52390 | -14.13887 | 93.88969 |
| 13 | -5.77530 | -6.38160 | 120.09886 |
| 14 | -5.20190 | 32.17731 | 148.79232 |
| 15 | -4.80110 | 37.28981 | 178.87394 |
| 16 | -4.46720 | 61.43883 | 211.49716 |
| 17 | -4.31230 | 21.87896 | 243.05841 |
| 18 | -4.22950 | 111.18016 | 275.10517 |
| 19 | -4.28950 | 86.22785 | 304.41217 |
| 20 | -4.37500 | 129.06332 | 333.99189 |
| 21 | -4.68450 | 129.49877 | 355.33530 |
| 22 | -5.14680 | 130.50775 | 369.77262 |
| 23 | -5.69220 | 160.85045 | 379.54376 |
| 24 | -6.16050 | 157.40697 | 391.58562 |
| 25 | -6.91420 | 171.99391 | 389.59751 |
| 26 | -7.49220 | 164.43201 | 394.25940 |
| 27 | -8.30400 | 151.14282 | 387.21359 |
| 28 | -9.09800 | -157.76393 | 380.04164 |
| 29 | -10.03340 | -166.62816 | 366.05354 |
| 30 | -10.88320 | -153.35043 | 355.23740 |
| 31 | -11.79720 | 163.63445 | 341.41226 |
| 32 | -12.75110 | -129.88093 | 325.94515 |
| 33 | -13.75480 | -150.12411 | 308.82046 |
| 34 | -14.68520 | -170.15070 | 294.52371 |
| 35 | -15.80760 | -111.91813 | 274.26837 |
| 36 | -16.67600 | -171.53898 | 262.57316 |
| 37 | -17.73060 | -151.81376 | 245.64324 |
| 38 | -18.65610 | -107.18206 | 232.90226 |

Figure 5.2 Program BALP Printout of LP Seismograph Responses Between 79.4 and 16.7 Seconds/Cycle

## SECTION VI

## MAINTENANCE

### 6.1 General

Maintenance activity at LASA includes correction of failures, preventive maintenance, modifications, special tests required for evaluations or quality control activities, facility and access maintenance, improvements, and vehicle maintenance. LASA maintenance activity is divided into three different categories: Data Center (LDC), Maintenance Center (LMC) and Facilities Support. The LDC in Billings covers the following five systems: the IBM 360/44 computer, the DEC PDP-7 computer, LDC Digital, LDC Analog, and the LDC Test and Support. The LMC located in Miles City maintains all array equipment systems which are comprised of SP Sensor, LP Sensor, Meteorological, SEM, and Power. Facilities Support provides maintenance of buildings, vehicles, land leases, and array facilities such as cable trenches, access trails, fences, WHV sites, and CTH sites.

### 6.1.1 Philosophy

During December to January weather and road conditions usually limit travel to the sensor locations. During these months the maintenance effort is concentrated on shop repair and testing of seismometers, seismic amplifiers and printed circuit cards. Trips to the array are made only for emergency repairs or when weather and road conditions permit.

### 6.1.2 Summary

Array equipment maintenance completed at LMC included completion of modification P-82, preventive maintenance, repairs at selected WHV locations and LP sensor channels, and shop repair of array equipment spares. The LDC effort centered mainly on the PDP-7 system, Develocorder, and preventive maintenance.

Table XXII summarizes the number of all equipment (LASA) and facility (utility) work order actions for this quarter. The 345 completed work orders represented 554 separate maintenance actions by technical personnel.

The number and type of operational equipment failures corrected are discussed in paragraph 4.2. Work orders are used to document all LASA maintenance activities. The actual time or complexity required for a task is not indicated but the summary does indicate the type of work performed and the size of the work load. Unusual weather conditions for a Montana winter allowed considerable travel in the array. Except for two periods of extreme winter conditions, travel in the array was possible.

TABLE XXII

WORK ORDER SUMMARY

DECEMBER 1972 - FEBRUARY 1973

| WORK ORDER TYPE | BACKLOG START OF QTR | INITIATED | COMPLETED | BACKLOG END OF QTR |
|---|---|---|---|---|
| LASA: | | | | |
| System - A | 16 | 205 | 204 | 17 |
| Subassembly - B | 50 | 19 | 57 | 12 |
| Component - C | 69 | 17 | 62 | 24 |
| Total | 135 | 241 | 323 | 53 |
| Utility: | | | | |
| Cable trench & trail inspection | 0 | 11 | 6 | 5 |
| Cable trench backfill | 0 | 0 | 0 | 0 |
| WHV sites landscaped | 0 | 3 | 3 | 0 |
| Marker posts & or WHV covers replaced | 0 | 3 | 2 | 1 |
| CTH maintenance | 1 | 6 | 7 | 0 |
| Vehicle maintenance and inspection | 0 | 4 | 4 | 0 |
| Fence inspections | 2 | 3 | 0 | 5 |
| Trail repairs | 0 | 0 | 0 | 0 |
| Total | 3 | 30 | 22 | 11 |
| WORK ORDER TOTALS | 138 | 271 | 345 | 64 |

## 6.2 Data Center

### 6.2.1 System 360

Three failures in the System 360 computer initiated maintenance actions. A December report from SAAC of an excessive number of improper data records resulted in a thorough check of the LDC 360 system with no troubles detected. Later, Telco circuits proved to be responsible. The 1052 typewriter cycle clutch jammed and ruined the drive belt. Cleaning, repacking the cycle cluth, a new drive belt and mechanical realignment restored the unit's operation. Failure of an 1827 Data Adapter logic card (A33H) prevented its remote operation. The function was jumpered until a replacement card arrived.

### 6.2.2 System PDP-7

Mechanical troubles in the tape units, the teletypewriter, and the card reader generated the PDP-7 computer maintenance this quarter. The already worn condition of the DEC 570 tape units was further evidenced by failures with door springs, lamps, solenoid daiphrams, photo sensors and vacuum motor brushes. A stripped nylon drive gear in the KSR-35 teletypewriter required replacement of the gears, the print block and hammer. The condition requiring frequent and critical electrical timing adjustments on the DEC card reader was corrected by a mechanical alignment. Mechanical timing is provided by automative-type ignition points whose gaps narrow with wear from the rubbing blocks.

### 6.2.3 Other LDC Equipment

Overhaul of the second Develocorder during this contract has now been completed. Proper operation of both Develocorders was verified from on-line film recordings.

The deteriorating effect of Develocorder chemicals upon copper drain pipes was demonstrated shortly after the initial installation of the Develocorder rack and drain system. Replacement of the copper pipe drain system with plastic (PVC) pipe was completed. One short vertical section of copper, connecting the PVC pipe to the drain, was not replaced. Now this pipe has been completely dissolved by the long term chemical action. A replacement was fabricated using galvanized nipples and a pipe union. The life expectancy of the galvanized pipe is shorter than PVC but the pipe union will facilitate future replacements.

## 6.3 Maintenance Center

The LMC maintenance efforts are divided into two activities: array tasks and shop testing and repairs.

### 6.3.1 Array Activities

During this period, 67 field trips covering 9,975 miles and one trip to the PMEL at Great Falls to pick up and deliver test equipment for calibration were made. All subarrays were visited for preventive maintenance checks and for adjustment of the dc offset on the SEM SP input channels to within ± 5 mV.

Installation of the SP Channel CTH Gain Control Modification at subarray E3 completes the first phase of this project in the array. Subarray adjustment of SP seismograph channel gain is being routinely scheduled and 34 subarray visits have been made since 29 September 1972; 20 were completed this quarter. Two different methods of selecting channels for adjustment are being used. At subarrays D2 and D3 the all channel gains are being set to nominal levels; both have received four adjustment visits. At the other subarrays the channel outputs are being set to limit the drift in channel gain to within a limited range over a limited time period. Of 19 subarrays all have been visited at least once for readjustment except B1 and E3; seven subarrays have had adjustments twice.

Visits to a number of WHV locations were possible for repair of SP sensors. Repair and/or replacement of 17 WHV panels and 3 seismometers were completed. At F3 the subarray leg 2 cable had to be spliced and repaired after being cut by the power company.

The SP Channel Status of the outstanding conditions in the SP array requiring maintenance attention as of 28 February 1973 is summarized in Table XXIII. Based on the five test criteria shown in the column headings, a total of 65 unsatisfactory conditions are reported. This large (124%) increase from the previous quarter results from the number of sensors with improper natural frequency. Previous status reports showed only those sensors whose natural frequencies measured out-of-tolerance. Those sensors whose frequencies had not been measured since installation were considered satisfactory. Now since nearly all sensors with recently measured unsatisfactory natural frequencies have been corrected, and the status report is being updated to include all sensors. To determine the natural frequency of the seismometers in which no recent tests had been made, the 1965 installation measurements were used. All with natural frequencies in excess of 1.0 ± .1 hertz are indicated as unsatisfactory and are being scheduled for testing and repair as necessary.

### 6.3.2 Shop Activities

Completion of the previously deferred work orders (Parts B and C) was the main objective this quarter. Shop repairs included: 62 printed circuit cards, 44 RA-5 amplifiers and panels, eight HS-10-1A seismometers, two SEM control drawers, one SEM

TABLE XXIII

SP CHANNEL STATUS, 28 FEBRUARY 1973

| SUBARRAY | CALIBRATION RESPONSE | | NATURAL FREQUENCY | | SENSITIVITY RESPONSE | | SEISMIC EVENT POLARITY | | SEISMIC EVENT AMPLITUDE | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SAT. | UNSAT. | SAT. | UNSAT. | SAT. | UNSAT. | SAT. | UNSAT. | SAT. | UNSAT. |
| A0 | 16 | 1 | 13 | 3 | 16 | 0 | 17 | 0 | 17 | 0 |
| B1 | 16 | 1 | 12 | 4 | 16 | 0 | 17 | 0 | 17 | 0 |
| B2 | 17 | 0 | 10 | 6 | 16 | 0 | 17 | 0 | 17 | 0 |
| B3 | 16 | 1 | 13 | 3 | 15 | 1 | 17 | 0 | 17 | 0 |
| B4 | 15 | 2 | 9 | 7 | 16 | 0 | 17 | 0 | 17 | 0 |
| C1 | 16 | 0 | 13 | 2 | 15 | 0 | 16 | 0 | 16 | 0 |
| C2 | 17 | 0 | 16 | 0 | 15 | 1 | 17 | 0 | 17 | 0 |
| C3 | 17 | 0 | 14 | 2 | 15 | 1 | 17 | 0 | 17 | 0 |
| C4 | 16 | 0 | 15 | 0 | 14 | 1 | 16 | 0 | 16 | 0 |
| D1 | 17 | 0 | 12 | 4 | 16 | 0 | 17 | 0 | 17 | 0 |
| D2 | 20 | 1 | 18 | 2 | 20 | 0 | 21 | 0 | 21 | 0 |
| D3 | 17 | 0 | 14 | 2 | 16 | 0 | 17 | 0 | 17 | 0 |
| D4 | 17 | 0 | 13 | 3 | 16 | 0 | 17 | 0 | 17 | 0 |
| E1 | 17 | 0 | 14 | 2 | 16 | 0 | 17 | 0 | 17 | 0 |
| E2 | 16 | 1 | 15 | 1 | 15 | 1 | 17 | 0 | 17 | 0 |
| E3 | 25 | 0 | 25 | 0 | 25 | 0 | 25 | 0 | 25 | 0 |
| E4 | 17 | 0 | 15 | 1 | 16 | 0 | 17 | 0 | 17 | 0 |
| F1 | 17 | 0 | 11 | 5 | 16 | 0 | 17 | 0 | 17 | 0 |
| F2 | 16 | 0 | 15 | 0 | 14 | 1 | 16 | 0 | 16 | 0 |
| F3 | 17 | 0 | 13 | 3 | 16 | 0 | 17 | 0 | 17 | 0 |
| F4 | 17 | 0 | 14 | 2 | 16 | 0 | 17 | 0 | 17 | 0 |
| TOTAL | 359 | 7 | 294 | 52 | 340 | 6 | 366 | 0 | 366 | 0 |

output drawer, one LP Type II amplifier, and the modification of the SEM drawer test unit to accomodate changes for modification P-82.

## 6.4 Facilities Support

Based on the slow run-off of snow this year, a minimum of damage is expected. Some sites are bare of snow and dry. Unless heavy spring rains occur, no serious problems are anticipated. Subarrays E4 and F4 were throughly inspected and all restoration completed.

Fifty six landowners were contacted regarding array operations and lease agreements. Twenty-two utility work orders were completed.

## SECTION VII

## ASSISTANCE PROVIDED TO OTHER AGENCIES

### 7.1 Seismic Data Laboratory (SDL)

Ninety Develocorder film recordings of selected SP sensor data were made for SDL. Each film covers a period of approximately 24 hours; film change is made at about 1800 GMT. The format was changed on January 8 to the following: F4-10, F1-10, F3-10, F2-10, A0-10, A0-10 attenuated, E3-10, E3-73, and E3-75.

### 7.2 National Earthquake Information Center (NEIC)

Assistance is now being provided to NEIC in Boulder which consists of aiding in the rapid location of large earthquakes and the reporting of detection times of regional and near-regional events. Both efforts use the Develocorder film recorded for SDL (see para. 7.1) prior to their shipment. The release of this data/information has had the prior approval of the AFTAC Project Officer.

### 7.3 Weather Bureau

The Billings Weather Bureau office continues their request for periodic weather information from the outputs of the array's temperature, wind direction and speed, barometric presure, and rainfall sensors. Three times each day a complete report of the latest available data are provided to them by the LDC operators.

### 7.4 Visitors

Dan Hoye and Darrell Small, DCASD Seattle, toured the LDC and discussed quality control of government property on February 16.

## SECTION VIII

## DOCUMENTATION PROVIDED UNDER VT 2708

8.1 <u>Technical Reports/Letters</u>

The following documents were prepared during this period:

(1) Montana LASA Fourth Quarterly Technical Report, Project VT 2708, T/R 2056-72-28, 15 Dec. 72.

(2) "Operation and Maintenance of LASA Monthly Progress Report" December 1972, T/R 2056-72-29.

(3) "Operation and Maintenance of LASA Monthly Progress Report", January 1973, T/R 2056-73-30.

(4) "Montana LASA Long-Period Seismograph Broadband Calibration Response Measurements" T/R 2056-73-31, 23 Feb. 73.

(5) "Measurement of the Amplitude and Phase Response of the LASA Seismographs" T/R 2056-72-32, 23 Feb. 73.

(6) "Regional and Near Regional Detections at LASA" 21 Feb. 73.

8.2 <u>Operations Data</u>

(1) "Defective Signal Channel Status Report" issued weekly.

(2) "Data Interruption Log" issued weekly

(3) "Develocorder Operations Log" issued weekly.

(4) "LASA Regional/Near Regional Detection Bulletin" issued weekly starting 14 Feb. 73.

The above data reports were distributed to using agencies as approved by the Project Officer.

8.3 <u>Alternate Management Summary Reports</u>

Three Alternate Management Summary Reports (AMSR) were prepared and distributed from Philco-Ford C&TS Division Headquarters; one for each of the months December, January and February 1973.



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## REFERENCES


1. Philco-Ford Corp. Montana LASA Second Quarterly Technical Report, ESD-TR-68-428 (AD 846 155) Billings, MT., Nov. 68, Appendix A.

2. Philco-Ford Corp. Montana LASA Final Technical Report, Project V/T 1708, T/R 2039-71-13 (AD 738 003) Billings, MT. 22 Dec. 71, pp 33-35.

3. ibid., pp 127-131.

4. Matkins, R. E. "Seismograph Calibrations Using Pseudo-Random Binary Sequences" T/R 2056-72-19, Philco-Ford Corp., Billings, MT, 19 April 72.

5. Philco-Ford Corp. Montana LASA Fourth Quarterly Report, Project V/T 2708, T/R 2056-72-28, Philco-Ford Copr. Billings, MT, 15 Dec. 72, pp 65-67.

6. Matkins, Lidderdale, and Smith, "Measurement of the Amplitude and Phase Response of the LASA Seismographs" T/R 2056-73-32, Philco-Ford Corp. Billings, MT. 23 Feb. 73.

7. Matkins, R. E. "Montana LASA Long-Period Seismograph Broadband Calibration Response Measurements" T/R 2056-73-31, Philco-Ford Corp. Billings, MT. 23 Feb. 72.